LUNAR SURFACE MOBILITY SYSTEMS COMPARISON AND EVOLUTION STUDY (MOBEV)

FINAL PRESENTATION REPORT

BSR 1464

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NOVEMBER 1966

THE Bendix CORPORATION

LUNAR SURFACE MOBILITY SYSTEMS COMPARISON AND EVOLUTION STUDY (MOBEV)

FINAL PRESENTATION BROCHURE

BSR-1464

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Approved: C. J. Weatherred
C. J. Weatherred, Director

THE BENDIX CORPORATION
BENDIX SYSTEMS DIVISION
ANN ARBOR, MICHIGAN

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VEHICLE NOMENCLATURE

The following nomenclature is used throughout the brochure and was adopted to facilitate recognition of the large number of vehicles and missions considered.

ROVING VEHICLES

1. First (letter) (R) defines vehicle as Rover.

2. Second (number) (0 through 3) defines vehicle crew size.

3. Third (letter) (A through D) defines specific mission of vehicle.

4. Fourth (letter) (E or B) defines vehicle as being Exploration or Base Support vehicle.

Example: R1BE (rover—one man—one-man vehicle B mission—exploration vehicle)

FLYING VEHICLES

1. First (letter) (F) defines vehicle as Flyer.

2. Second (number) (0 through 3) defines vehicle crew size.

3. Third (letter) (A through E) defines specific mission of vehicle.

Example: F1B (flyer—one man—one-man vehicle B mission)

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AGENDA

- INTRODUCTION
- PROGRAM DESCRIPTION
- SPACECRAFT DERIVATIVE STUDY
- METHODOLOGY CONCEPT FOR MOBILITY PLANNERS
- MOBILITY REQUIREMENTS AND CONSTRAINTS
- TECHNICAL AND RESOURCES DATA
- METHODOLOGY
- CONCLUSIONS AND SUMMARY

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NASA
LUNAR SURFACE MOBILITY SYSTEMS COMPARISION AND EVOLUTION STUDY

MOBEV

Final Presentation

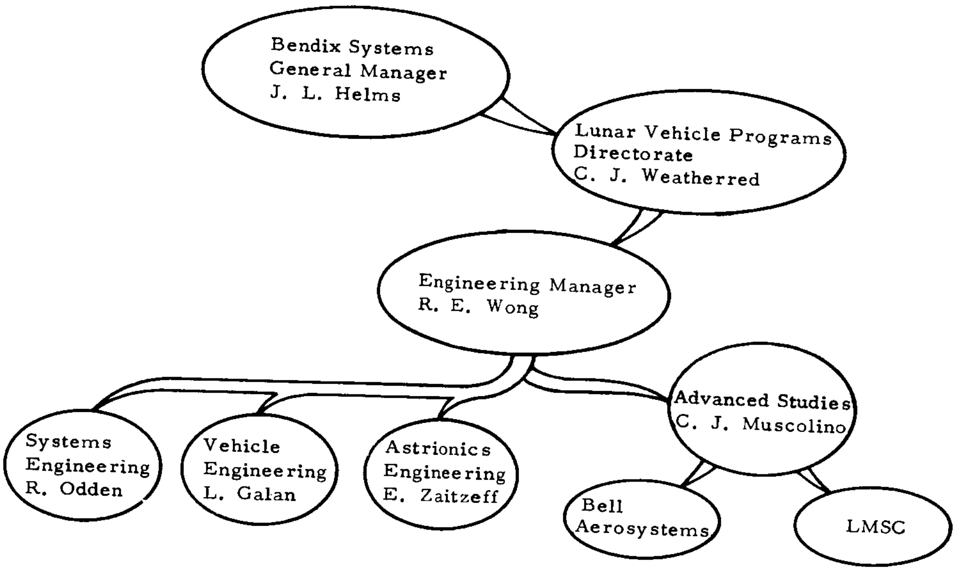
The Bendix Corporation
Systems Division
Ann Arbor, Michigan

MOBEV 3-1-1166

PROGRAM ORGANIZATION

The MOBEV Program was conducted by the Advanced Studies Group of the Lunar Vehicle Programs Directorate at Bendix Systems Division. Technical support was provided by the Advanced Studies, Systems, Vehicle, and Astrionics Engineering Groups at Bendix, and via subcontracts with the Bell Aerosystems Company and the Lockheed Missiles and Space Company. The program organization is shown on the accompanying illustration.

PROGRAM ORGANIZATION



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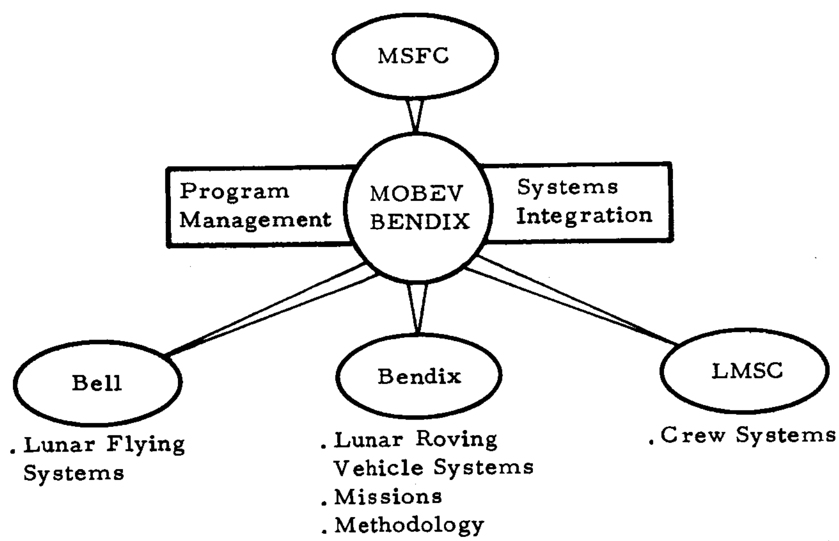
MOBEV TEAM

The MOBEV Program under direction of MSFC was conducted at Bendix Systems Division with subcontracts to Bell Aerosystems and Lockheed Missiles and Space Company.

In addition to program management and systems integration, Bendix has been responsible for lunar roving vehicle systems, missions analysis, and methodology development and validation.

Bell has been responsible for lunar flying systems; Lockheed, for the lunar roving vehicle crew systems.

MOBEV TEAM



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STUDY OBJECTIVES

Three major objectives have been identified for the study. The first involves development of a complete spectrum of rovers and flyers to satisfy lunar exploration needs during the 1970-to-1980 time period. Rovers include both manned and unmanned types and will be utilized for exploration, site survey, and base support operations. Flyers will be constrained to open cockpit manned operations and will include rescue and exploration missions.

The second objective involves the development of a methodology for selecting evolutions of lunar mobility systems for use by mobility planners.

The third objective involves determination of feasibility of Apollo spacecraft derivatives for mobility application. Specifically, the study will develop and evaluate MOLEM, MOCOM, and MOCAN designs derived from the Lunar Module (LM), Command Module (CM), and Multi Mission Module (CAN).

Additionally, the study is constrained to make maximum use of Apollo technology and will be bounded by presently defined and uprated capabilities of the Surveyor, LM, LM-Shelter, LM-Truck, LM-Taxi, and LLV(s) delivery systems.

STUDY OBJECTIVES

1. Develop concepts and data for a spectrum of lunar mobility systems

2. Develop and validate a Methodology for evolution selection

3. Determine feasibility of spacecraft mobility derivatives

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PROGRAM DESCRIPTION

MOBEV

Final Presentation

MOBEV 3-6-1166

SPEAKER: CARL MUSCOLINO

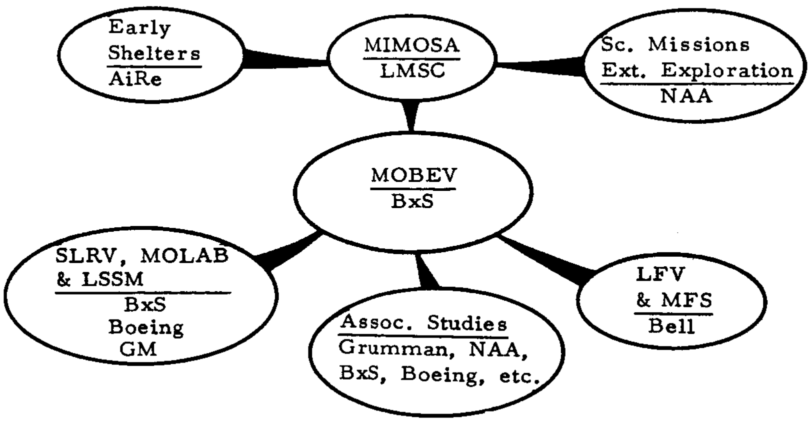
RELATED STUDIES

MOBEV serves as the focal point for past and present roving and flying vehicle conceptual efforts. It represents the first time in which all of the necessary factors have been brought to bear for purposes of defining a group of conceptual designs to a common base. These designs cover specific mobility gaps within a large spectrum.

MOBEV is one of a series of four advanced planning studies of lunar surface operations. These studies have been conducted concurrently, and include the following: (1) Mission Modes and System Analysis for Lunar Exploration (MIMOSA), (2) Early Lunar Shelters (ELS), and (3) Scientific Mission Support for Extended Lunar Operations (SMSELE). Data exchange and coordination between these studies was made through the MIMOSA Study, which utilized and integrated the various inputs. Further, the MIMOSA team included three of the four study prime contractors; Lockheed, Bendix, and Air Research.

Additional studies, past and concurrent, which significantly relate to MOBEV are also shown on the accompanying slide. These include system studies of rovers and flyers, scientific mission support studies, lunar exploration concept studies, and the spacecraft studies required to develop and analyze mobility derivatives.

RELATED STUDIES



LM Studies
CM/SM Studies
Sc. Missions
Multipurpose Mission Module
LESA Studies

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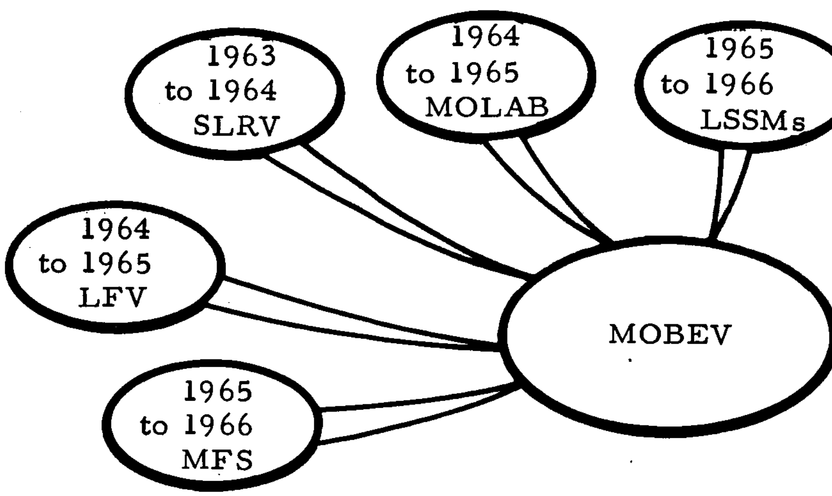
MOBILITY SYSTEM DATA BASE

The study of lunar surface vehicle systems has been underway for some time by various Government agencies and private industry. In early 1961 Bendix initiated efforts toward roving vehicle concepts and developed conceptual designs of Prospector size vehicles. Early flyer efforts were also underway by Bell Aerosystems. These studies continued on a conceptual basis until 1963. At this time detailed studies including resources analyses were started for the Surveyor Lunar Roving Vehicle (SLRV). Subsequently, preliminary design and resources planning studies were made of a Mobile Laboratory (MOLAB), several versions of a Local Scientific Survey Module (LSSM), the Lunar Flying System (LFV), and the Manned Flying System (MFS).

The availability of the technical and resources data from the last five studies discussed above provides the technological base for MOBEV to develop and study over 33 lunar surface mobility systems. Normalized and modified versions of these vehicles are included in the MOBEV vehicle spectrum. Other Design Point Vehicles in the spectrum were developed and analyzed based on the technical and resources data depth provided by these studies.

MOBILITY SYSTEM DATA BASE



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TECHNICAL APPROACH

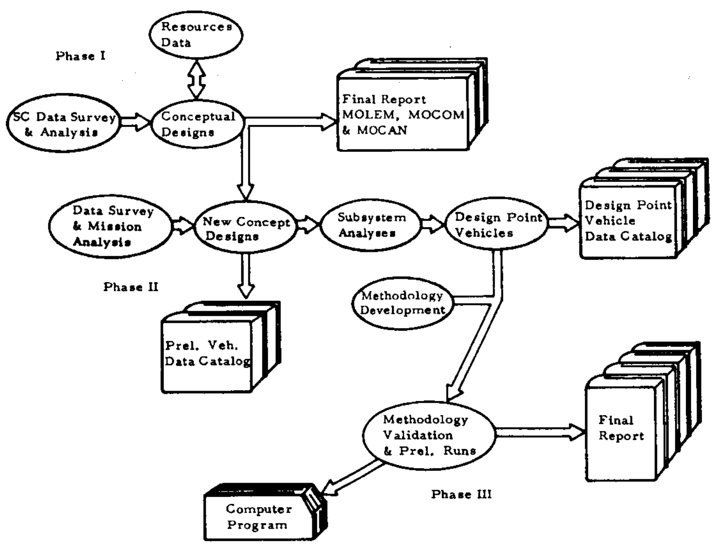
The technical approach is shown in flow chart form for major study elements. The elements are grouped within each phase. Major outputs from each element are shown just outside the phase groups.

Three major study elements are shown for Phase I. The first combines a data survey and analyses and results in the definition of a stripped LM, C/M, and CAN, applicable for development into mobility systems. The conceptual design element involves five tasks in the Statement of Work: (1) baseline configuration development, (2-4) establishment of subsystem designs, performance, and sensitivity, and (5) definition of resulting mobility derivatives. The final element is the establishment of resources data for each of the resulting mobility derivatives.

Phase II involves the mainline mission analysis-system engineering and the parallel development of an evolution methodology. Vehicles resulting from the Phase I study are candidate inputs for the initial mobility system spectrum in Phase II.

The Phase III methodology implementation utilizes Phase II Design Point Vehicle (DPV) data and methodology logic. The phase task includes a formal validation of the methodology based on NASA-recommended test cases and assistance in installing the methodology computer program in the NASA Huntsville facility.

TECHNICAL APPROACH



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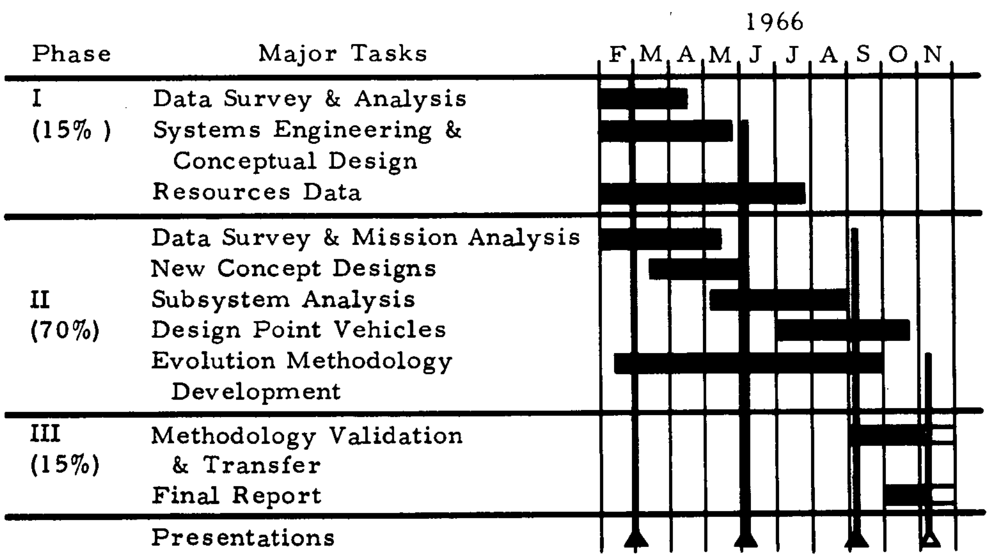
PROGRAM SCHEDULE

The MOBEV study schedule is shown on the accompanying illustration. Phase I and II of the program were conducted concurrently. The initial phase was essentially completed and reported on during the First Interim Presentation. This presentation also included results of the Phase II mission analysis and new conceptual designs. The remainder of the Phase II effort continued through October, with the major work on completion of the Evolution Methodology Development and definitions of the selected DPVs reported on in detail during the Second Interim Presentation.

The final phase began in September and includes validation and transfer to NASA of the methodology, and preparation of the Final Reports. This final presentation summarizes the results of all phase efforts.

PROGRAM SCHEDULE



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SPACECRAFT DERIVATIVE STUDY (MOLEM, MOCOM & MOCAN)

MOBEV

Final Presentation

MOBEV 3-11-1166

SPEAKER: CARL MUSCOLINO

SPACECRAFT DERIVATIVE STUDY OBJECTIVES

The objective of the spacecraft derivative study is to prepare vehicle conceptual designs derived from present Apollo spacecraft. The existing spacecrafts are the Apollo Lunar Module (LM), the Apollo Command Module (CM), and the Multi-Mission Module (CAN). The conceptual designs are based on the primary guideline of retaining as much of the existing spacecraft systems as possible. However, the final weight and performance characteristics of the resulting system must be within the LM-Truck delivery volume and weight capability.

SPACECRAFT DERIVATIVE STUDY OBJECTIVES

- Mobility Concepts
  - LM
  - CM
  - MMM
- Resources Data
- Feasibility

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SYSTEM DEVELOPMENT APPROACH (MOLEM, MOCOM, MOCAN)

The existing spacecraft data are reviewed and analyzed to identify components which serve no useful function in a mobility system. For example, the heat shield and re-entry communications systems on the CM, and the ascent engine as well as the reaction control systems on the LM are not required for a mobility system. Such items are deleted. The remaining functional subsystems are retained, thus defining the stripped spacecraft.

Added and/or modified subsystems are thus included to complete the preliminary configuration of a mobility concept. Performance requirements of the Bendix MOLAB concept are imposed upon the individual subsystems. Weight and performance sensitivities are determined for each subsystem with particular emphasis on weight.

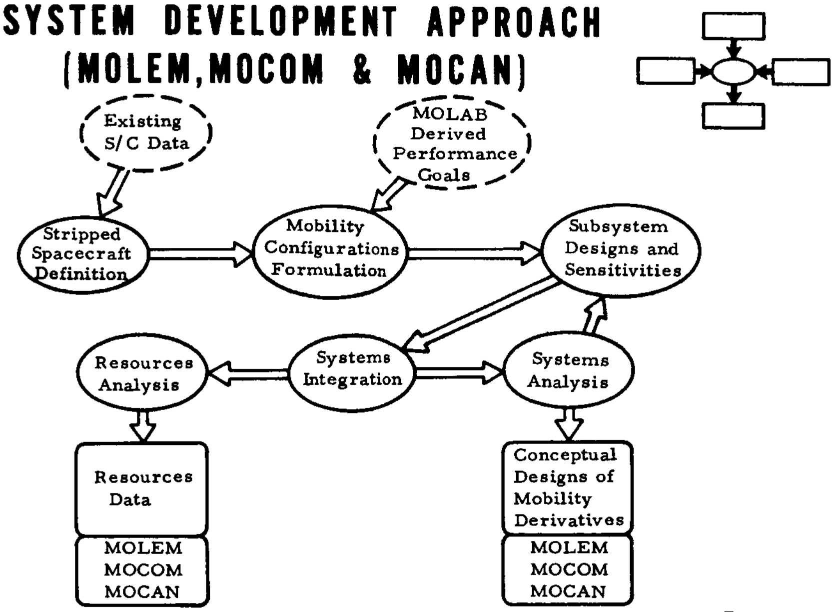
The development of the mobility derivative is by an iterative process. The subsystem sensitivities data are received by the systems group and an estimate of the operating mass of the vehicle is made. This involves estimating the mobility subsystem weight, and the power and duty cycle requirements of mobility dependent and independent subsystems. The power subsystem mass necessary to meet these requirements is thus established, and a gross operating mass of the vehicle determined. These data are fed into a computer program to calculate the mobility subsystem power and energy required to achieve the performance goals. A new set of power requirements is calculated resulting in a new power subsystem weight and system gross operating weight. The gross operating weight is checked against the previous estimate to determine any change to the mobility subsystem weight, and the iterative process continues until a match is made.

The resulting mobility derivative weight is then compared to the LM-Truck payload mass limit and recommendations for subsystem changes made when the system is overweight. The recommendations are then acted on by the subsystem group(s) in new or modified designs and sensitivity data.

The whole iterative process is continued until a mobility derivative with the desired performance characteristics, and compatible with the LM-Truck payload mass and volume constraints, is achieved. Data are then supplied by systems engineering to resources analysis where the pertinent resources data are developed and compiled.

The selected conceptual designs resulting from this procedure provide maximum performance within the carrier vehicle volume and mass restraints while maintaining maximum use of Apollo existing equipments.

SYSTEM DEVELOPMENT APPROACH (MOLEM, MOCOM & MOCAN)



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REQUIREMENTS AND CONSTRAINTS

The stowage configuration and delivered mass of the MOLEM, MOCOM, and MOCAN are constrained by the LM-Truck carrier vehicle, and the performance goals are based on the accomplishment of the MOLAB mission. This mission consists of a one and one-half figure eight within an 80-km radius of the starting point. The theoretical straight-line traverse is 274 km and the total range requirement is 400 km. The vehicle mission duration is set at 14 earth days. An emergency contingency for life support of seven days and a premanned mission lunar stand-by period of up to six months are also required. The mission can take place during lunar day or night and the vehicles are required to operate over a 50/50 Maria and Highlands ELMS surface models. A scientific payload of 320 kg and 73 kwh of scientific energy must be accommodated by the mobility systems. Remote control capability and a total of 40 crewmen ingress/egress cycles have been stipulated.

In line with the objective of the study, existing components and subsystems will be stripped if they are not functional, and as required to meet the LM-Truck mass restraint. A limitation on stripping of existing hardware is the basic cabin pressure shell which must be retained to have a spacecraft derivative. Within this ground rule, relaxation of range and duration performance requirements are allowed for those spacecraft which cannot meet the delivery mass constraint.

REQUIREMENTS & CONSTRAINTS
(MOLEM, MOCOM & MOCAN)

● Storage Envelops & Mass	LM/Truck, 3860 Kg (max)
● Crew Size	Two, 95th Percentile
● Scientific Mission Duration	14 Days (+7 Day Life Support Contingency)
● Lunar Standby Period	Six Months
● Operating Period	Lunar Day and/or Night
● Scientific Payload & Energy	320 Kg and 73 KwH
● Mobility Range & Radius	400 Km and 80 km
● Surface Model	ELMS: 50/50 Maria & Highland
● Ingress/Egress Cycles	40
● Vehicle Operation	Manned & Remote Control

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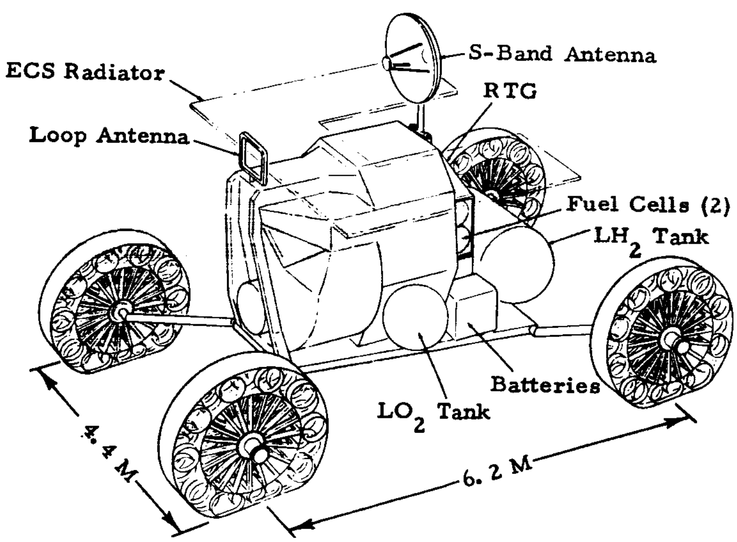
MOLEM CONFIGURATION

This illustration presents a perspective of the MOLEM. The cabin is a modified LM ascent stage and is mounted on an aluminum box beam frame supported by two pairs of metal-elastic wheels. The wheels are folded for unmanned delivery on the LM-Truck. The ECS radiators, S-band communications antenna, and a direction-finding loop antenna are located on top of the cabin. Scientific equipment lockers are located at the rear platform. The RTG, batteries, liquid hydrogen tank, fuel cells, primary power accessories, and the mobility control unit are located on the aft platform. Liquid O_2 tanks are located on each side of the cabin.

MOLEM CONFIGURATION



Range	400 Km
Payload	320 Kg
Duration	14 Days
Crew Size	2 Men

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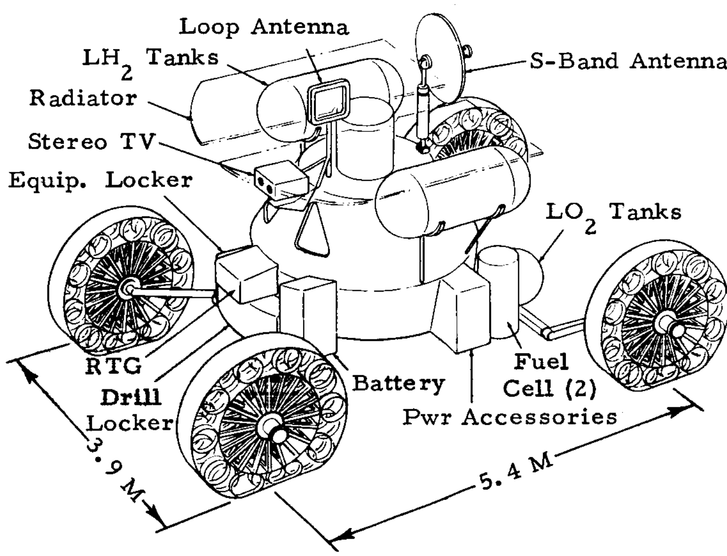
MOCOM CONFIGURATION

This illustration shows the resulting MOCOM configuration. The cabin is mounted on the chassis with the major axis of the Command Module cone in a vertical position. This is done to accommodate the design of the docking adaptor. The astronaut position in the cabin and internal furnishings and operational equipment are revised to compensate for the attitude change between the MOCOM and the Command Module from which it was derived.

MOCOM CONFIGURATION



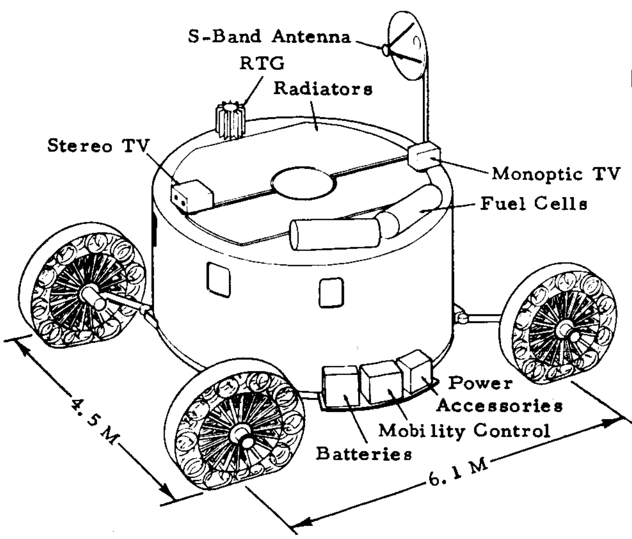
Range	400 Km
Payload	320 Kg
Duration	14 Days
Crew Size	2 Men

MOCAN CONFIGURATION

This illustration shows a perspective view of the MOCAN configuration. The MOCAN uses the MOLAB wheels and the Boeing CAN basic structure. The Apollo Multipurpose Mission Module (CAN) is mounted on a rectangular aluminum box beam frame and supported by four 203-cm (80-in.) diameter metal-elastic wheels. The CAN is designed to utilize fully the volume on top of the LM-Truck and within the Spacecraft LM Adaptor (SLA).

As stated previously, the MOCAN mission was reduced to an 8-day duration and a 200-km range in an effort to bring the vehicle weight down to within the LM-Truck payload capacity. The weight savings effected by this reduction in mission performance are mobility (34.1 kg), power (200 kg), and life support expendables (57.7 kg) for a total weight savings of 291.8 kg. This reduces the MOCAN delivered weight from 4077 kg to 3785 kg, which is within 3860-kg LM-Truck payload capacity.

MOCAN CONFIGURATION



Range	200 Km (400Km)*
Payload	320 Kg
Duration	8 Days (14 Days)*
Crew Size	2 Men

*Req's Addt'l LM/Truck Payload

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SYSTEM CHARACTERISTICS COMPARISON (MOLEM, MOCOM AND MOCAN)

Comparison of significant characteristics for MOLEM, MOCOM, and MOCAN shows that each of the designs provides for a crew of two and a scientific payload of 320 kg for a 14-day mission with a 400-km range. The only vehicle exceeding the LM-Truck payload capability of 3860 kg for a full-up mission is the MOCAN. Since the delivery mass constraint has been exceeded, MOCAN degraded performance to a 200-km, 8-day mission is shown in order that it can meet the assumed LM-Truck payload.

The cabin free volumes, with the exception of MOLEM, are within the NASA stipulated desired volume of 175 cu ft for a two-man, 14-day mission.

Fuel cell systems are used for primary power and are sized to supply the total energy requirements of 693, 695, and 734 kwh, respectively, for the MOLEM, MOCOM, and MOCAN. Mobility specific energy for MOLEM, MOCOM, and MOCAN is, respectively, 0.44, 0.49, and 0.59 kwh/km. The maximum average speed is 10 km/hr, over a 50/50 ELMS and 16.7 km/hr on a hard surface for all three vehicles. Obstacle and crevice negotiability is based on vehicle geometry. For MOLEM, MOCOM, and MOCAN, respectively, the obstacle negotiability is 80, 70, and 60 cm; and the crevice negotiability is 173, 157, and 146 cm.

Development costs of $\$273.3 \times 10^6$ for MOLEM, $\$282.3 \times 10^6$ for MOCOM, and $\$291.7 \times 10^6$ for MOCAN do not include the cost of 13 basic development shells or the flight shell. Development time for all three mobility derivatives is 4.75 years.

SYSTEM CHARACTERISTICS COMPARISON (MOLEM, MOCOM, & MOCAN)

	MOLEM	MOCOM	MOCAN	
Delivered Mass (kg)	3322	3535	4077	(3785)*
Cabin Free Volume (ft^3)	150	219	810	
Total Mission Energy (kwh)	693	695	734	(435)*
Mobility Specific Energy (kwh/km)	.44	.49	.59	(.52)*
Maximum Average Speed-ELMS (km/hr)	10.0	10.0	10.0	
Obstacle Negotiability (cm)	80	70	60	(70)*
Crevice Negotiability (cm)	173	157	146	(157)*
Development Cost ($\$10^6$)	273.3**	282.3**	291.7**	
Development Time (years)	4.75	4.75	4.75	

*Degraded Performance
**Do not include 13 basic shells

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CONCLUSIONS (MOLEM, MOCOM, AND MOCAN)

In conclusion, each of the derivative concepts studied is technically feasible.. The limited cabin volume of the MOLEM necessitates cramped living conditions, stand-up driving, and a minimal size airlock with questionable emergency operation capability. The MOCOM concept meets the cabin free volume and delivered mass restraints; however, it does not provide any weight margin for possible growth. The MOCAN with a free volume almost five times greater than required offers a large growth potential with respect to extensions in mission duration or increases in crew size. However, in order for the MOCAN delivered mass to meet the assumed LM-Truck payload, the range requirement must be reduced to 200 km and the mission duration must be reduced to 8 days.

Estimated development costs of the three vehicles are within the accuracy of the estimates, and, as noted earlier, do not include the cost of 13 basic spacecraft cabin shells required by each mobility derivative development.

The three mobility derivatives were not retained as MOBEV Design Point Vehicles since they do not offer the planner any measurable advantages in terms of performance, mass, or cost over a system which is designed specifically for mobility use such as MOLAB. Details of the technical and resources analysis of the MOLEM, MOCOM, and MOCAN designs investigated during this study are documented in the MOBEV Final Report.

CONCLUSIONS
(MOLEM,MOCOM & MOCAN)

- All concepts are technically feasible
- No appreciable resources requirement differences
- Mobility derivatives are not retained as MOBEV DPV's

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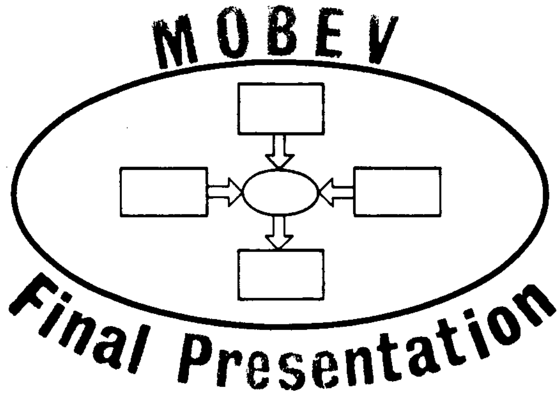
METHODOLOGY CONCEPT FOR MOBILITY PLANNERS



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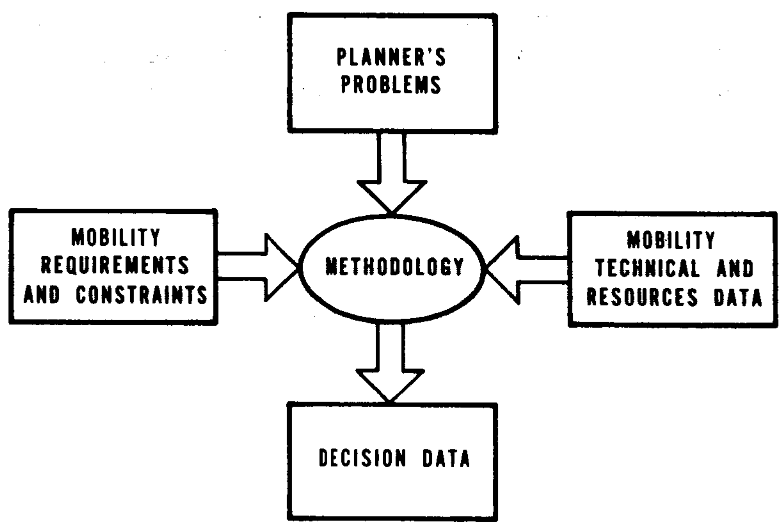
SPEAKER: CARL MUSCOLINO

MOBILITY PLANNER'S METHODOLOGY CONCEPT

The figure illustrates the objectives and interfaces of the MOBEV study. Common baseline technical and resources data are provided for a series of lunar mobility systems. These data and the methodology are the primary end items of the study. The methodology is a tool to assist mobility systems planners. This tool was specifically designed for the planner's problem.

The planner, in using the methodology, specifies mobility system performance requirements and constraints. The common baseline data are utilized to provide the planner with meaningful decision data.

MOBILITY PLANNER'S METHODOLOGY CONCEPT



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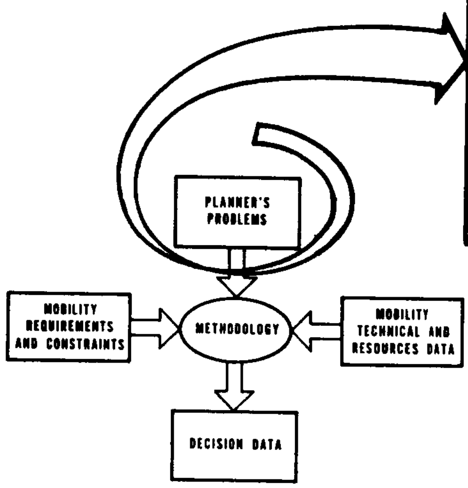
PLANNER'S PROBLEM

An identification of general problem types that the planner must solve is a necessary prerequisite to the design of the methodology and selection of performance criteria upon which Design Point Vehicles will be based.

There is one primary planner's problem for which the methodology is structured. This problem is selection of evolution of mobility systems which fulfill a sequence of missions over a time period of interest in a manner which offers the greatest advantage.

There are also a series of what may be termed subproblems with which the planner is concerned. Examples of these problems are the assessment of the effect of new lunar surface data or alteration of a planned funding rate.

PLANNER'S PROBLEMS



- Establish A Mobility Evolution Plan
- Assess Effects of Fiscal and Technical Changes
- Recommend Mission and Mode Considerations Resulting From Mobility Studies

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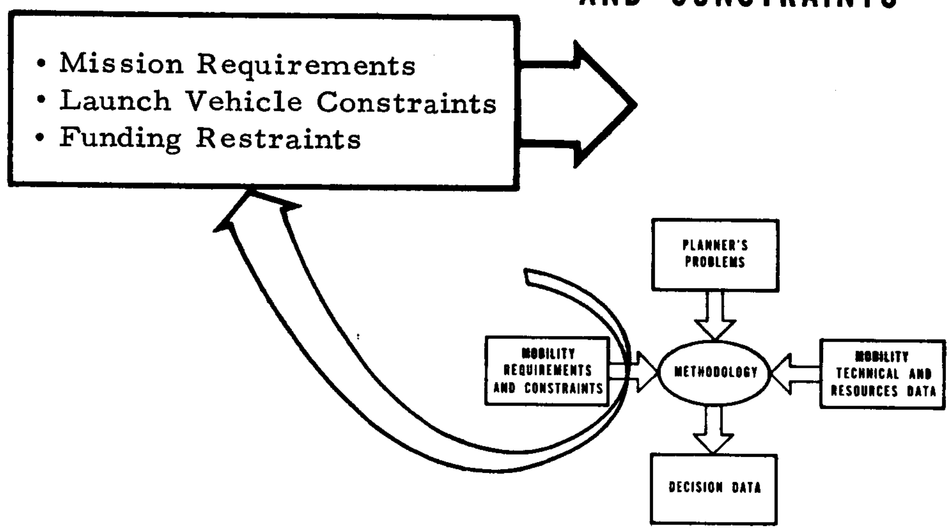
MOBILITY REQUIREMENTS AND CONSTRAINTS

For the solution of a planner's problem, specific mobility performance requirements and constraints must be inputted to the methodology.

Anticipation of the range of these requirements is necessary to define the design points for the MOBEV vehicles. In addition to the requirements definition, realistic constraints must be specified for the Design Point Vehicle to assure their compatibility with existing or planned launch and delivery systems.

MOBILITY REQUIREMENTS AND CONSTRAINTS



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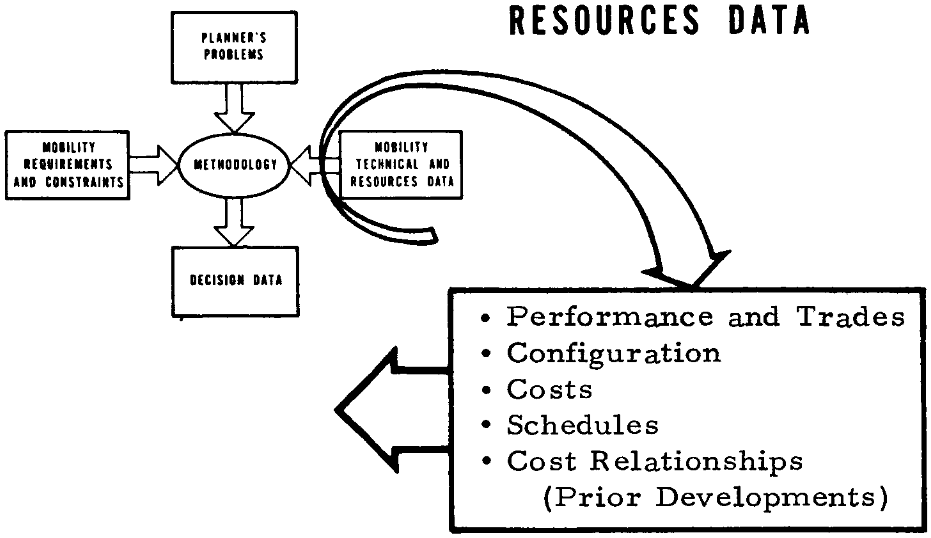
MOBILITY TECHNICAL AND RESOURCES DATA

The essential feature of the technical and resources data for the Design Point Vehicles is that they have a common baseline set of ground rules upon which they are based, thereby, allowing valid comparisons and evaluations.

Data which describe the characteristics and performance capability of each Design Point Vehicle are contained in both a DPV Data Book and within the computerized methodology. Some factors cannot be adequately treated by the computer, such as configuration compatibility, but the necessary drawings and data for manual evaluation of these factors are contained in the Data Book.

MOBILITY TECHNICAL AND RESOURCES DATA



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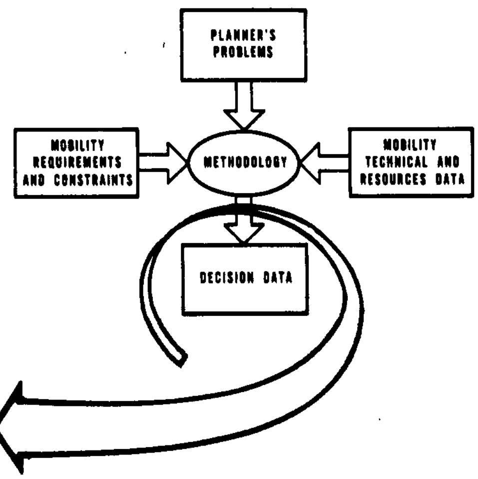
DECISION DATA

The type and quantity of data required to assist the planner in making mobility decisions are dependent upon the specific problem type. Some of the particular performance, cost, and schedule data required are identified in the illustration.

DECISION DATA



- Vehicle Sets (Evolutions)
- Total Cost Per Vehicle
- Funding Per Vehicle
- Total Cost of Sets
- Funding Per Set
- Vehicle Reject Reason

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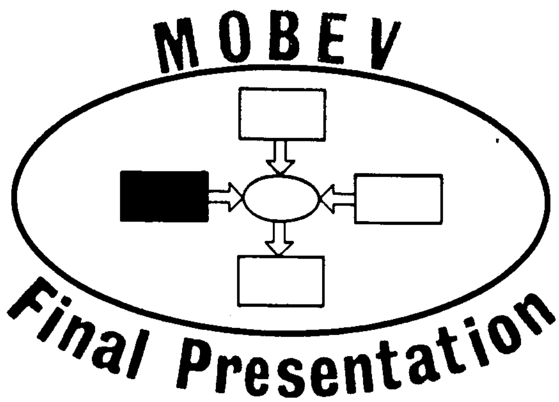
MOBILITY REQUIREMENTS AND CONSTRAINTS



MOBEV 3-26-1166

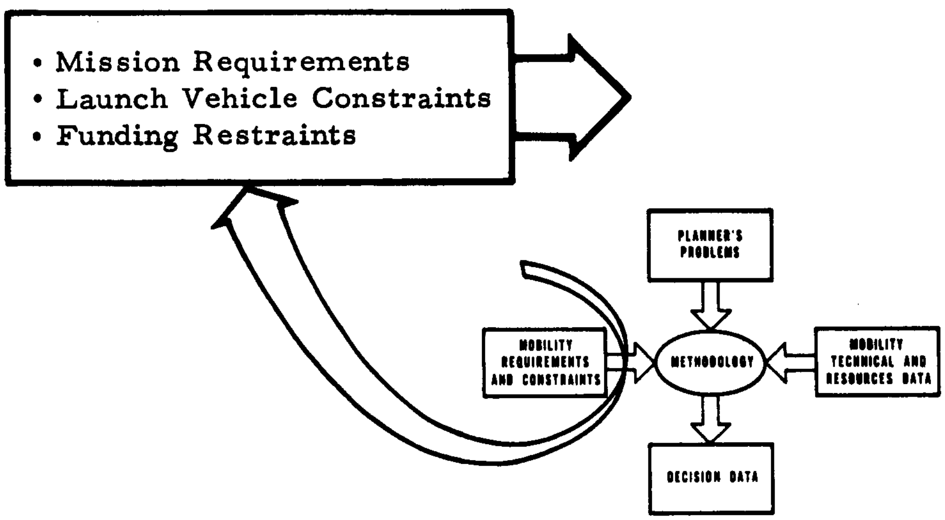
SPEAKER: WALT CROSMER

MOBILITY REQUIREMENTS AND CONSTRAINTS

From its inception through the decade of the 1970s, the lunar exploration program will be marked by rapid advances in establishing the role of the astronaut scientist in extraterrestrial exploration. The effectiveness of man in carrying out the program under the severe restrictions of the lunar environment depends on the capability of the exploration system in providing the support for the astronaut and his activities. There is a need for providing mobility for the astronaut to permit him to carry out his activities over an area rather than, effectively, at a point. It will also be necessary to transport cargo over the lunar surface to provide tools and instrumentation for the astronaut and for establishing scientific stations at distant sites. Activities at such sites include taking continuous data at permanent unmanned stations, collecting a specific set of observations at a site during a manned traverse, maintaining a semipermanent base for a set time period, or constructing a long-term facility such as an observatory.

A variety of vehicles is needed to meet exploration objectives throughout the program. The selection of an appropriate vehicle for a particular mission depends on a clear delineation of the mission objectives in the context of the overall program. The limit on the scope of lunar surface missions is implicit in the choice of delivery systems because of the limit on the size and number of payloads which can be delivered. Within this constraint wide variations in missions are possible and must be met by vehicles of greatly different characteristics. Another constraint on lunar surface mobility planning is the funding level to be applied. Although this constraint is of paramount importance, it must be considered in the environment of the overall national goals for all space programs, and, hence, is beyond the scope of this effort.

MOBILITY REQUIREMENTS AND CONSTRAINTS



MOBEV 3-23-1166

MISSION ANALYSIS

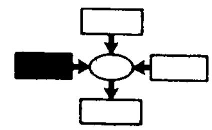
To define a mission spectrum from which to establish a complete spectrum of mission requirements for mobility systems, several factors must be considered.

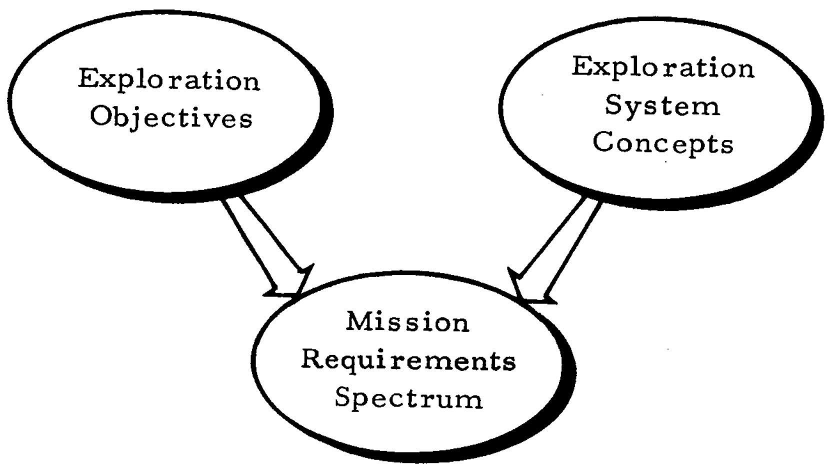
First, the objectives of lunar exploration and the place of the mobility system in meeting these objectives must be defined. The definition of these objectives was obtained from two primary sources: the scientific community desires, and the Scientific Mission Support Studies conducted for NASA. The most complete and up-to-date source of the scientific community appraisal are reports of two conferences held in the summer of 1965, one by the National Academy of Sciences and one by the Manned Space Coordinating Committee of NASA. Reports of these two conferences provide 15 major questions involved in exploration of the moon and specific recommendations for hardware development and mission implementation. The Scientific Mission Support Studies were conducted for AAP, ALSS, and LESA. These studies provide a basis for definition of scientific payloads, traverse requirements, and time utilization.

Next, the total exploration system concepts, mission equipment, delivery mode, and crew delivery schemes must be analyzed to determine the role of the mobility systems in the total exploration system. System studies reviewed were Surveyor, Apollo, AAP, ALSS, LESA, LLS Paylods, and MIMOSA Interim results.

Finally, after all the above information was assembled, the definition of the mission requirements spectrum was conducted. To define this spectrum several steps were taken. First, the existing requirements were listed. Then the limits of the manned vehicle requirements were established by analysis of what would logically constitute a maximum and a minimum manned mission consistent with the overall exploration objectives. Finally, logical steps which show intermediate mission capabilities between these established points were derived. A nominal mission was established for each point. Unmanned vehicle requirements were set up based on the SLRV (Surveyor Lunar Roving Vehicle) being the smallest vehicle. An upgraded, more versatile system is possible by utilizing a Surveyor delivery system launched from lunar orbit. An equipment carrier to assist a walking astronaut was postulated. Use of an LSSM specifically designed for remote use was considered to be the maximum specific unmanned vehicle requirement. Base support and LFV requirements spectrums were also established.

MISSION ANALYSIS



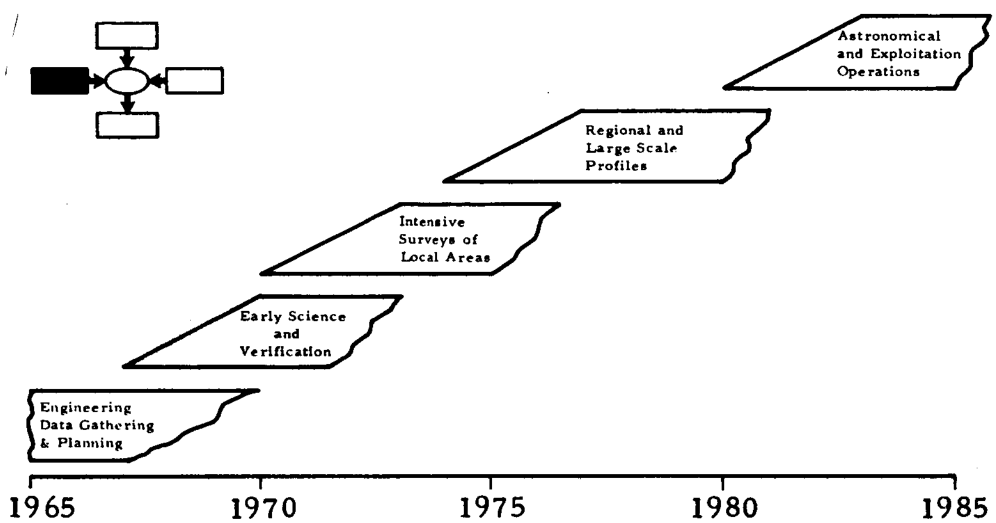


MOBEV 3-27-1166

LUNAR EXPLORATION OBJECTIVES DEVELOPMENT

This chart shows a general, time-phased arrangement of lunar exploration objectives. These objectives result from considerations of past efforts and projected future efforts. As shown on the chart, the objective of the present program (Ranger, Surveyor, Orbiter) is to gather the necessary data for detailed design of future spacecraft and for planning of future missions including site selection and scientific scaling. The objective of the next phase is to verify manned operational procedures and obtain preliminary scientific data. Following this, intensive geological and geophysical surveys of small local areas including long-term emplaced station observations will be accomplished. To extrapolate the data obtained in the local survey operations to a global or regional scale, long-range geological and geophyical profiles or paths will need to be obtained. The final phase of exploration consists of the establishment of astronomical observatories and possible exploitation of lunar resources for future interplanetary operations.

LUNAR EXPLORATION OBJECTIVES DEVELOPMENT



MOBEV 3-28-1166

EXPLORATION SYSTEM CONCEPT DEVELOPMENT

This chart shows a time-phased arrangement of the system concepts which can be utilized to accomplish the objectives presented in the previous chart.

The unmanned program, already in progress, has resulted in considerable new information about the lunar surface, e.g., bearing strength, roughness, slope. Further continuation of this program is possible, including lunar-orbit-launched probes carrying small lunar vehicles for expanding the data base.

The early manned program consists of short duration stays (2 to 5 days) and single launch missions (Apollo LM and Augmented LM). These missions could be augmented by small mobility units for short range reconnaissance and sample gathering.

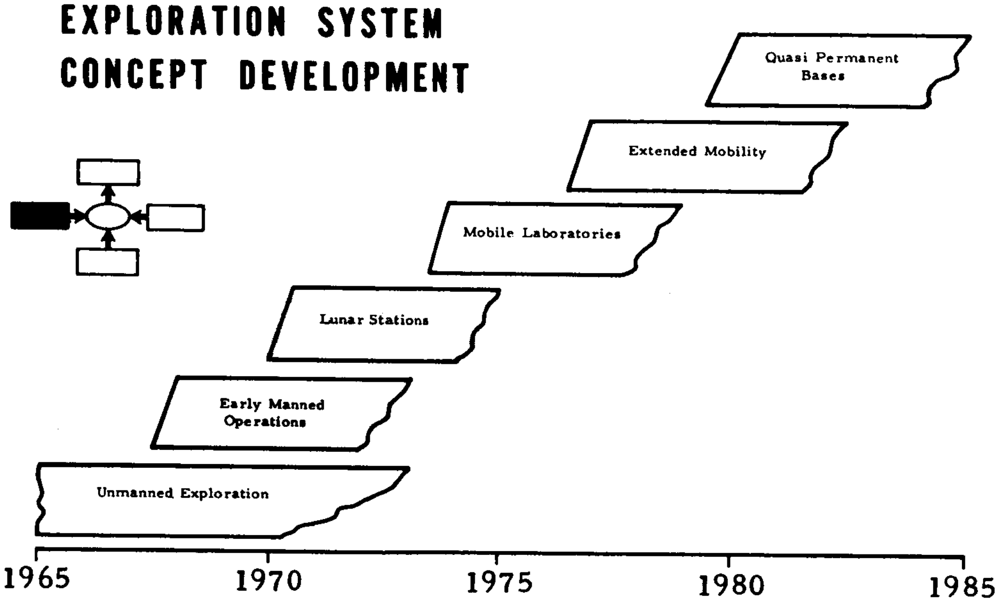
Lunar station concepts generally consist of two launches, the first containing the logistics payload made up of the shelter, mobility units, and scientific equipment, and the second being the personnel delivery. Open cabin vehicles used in conjunction with fixed shelters make up this mode and limit its radius of operations to PLSS duration limits. In more advanced versions a small enclosed cabin could be used to extend the operational limit.

Mobile laboratories are used to provide the capability for regional studies in the intermediate phases of exploration. These concepts generally consist of a self-contained cabin with crew provisions for 14 days or longer and mobility capability in excess of 400 km.

Extended mobility operations are necessary to perform the geophysical and geological profiling over the long-range paths as outlined in the MIMOSA scientific programs.

To perform any extended astronomical observations or exploitation of lunar resources, it is necessary to establish quasipermanent or permanent lunar bases. This is most probably the final phase of lunar exploration.

EXPLORATION SYSTEM CONCEPT DEVELOPMENT



MOBEV 3-29-1166

MOBILITY SPECTRUM—MISSION PARAMETERS

This chart shows the primary parameters used to describe the mobility spectrum; namely, range, duration, payload, and crew size. A number of other parameters could also have been considered such as mass-delivery system, radius of operations, and scientific man-hours. However, it is felt that these four parameters describe the mission requirements most simply and directly and the other factors are lower level and more system-requirements oriented.

Also shown on the chart are the ranges of coverage of each of the parameters by the individual, nominal mission requirements. The initial mission requirements established the maximum crew size at four men. This was later amended to three men based on considerations of MIMOSA crew delivery studies which resulted in two, three, or six men.

MOBILITY SPECTRUM
MISSION PARAMETERS

Range	5 to 4000 kilometers
Duration	3 hours to 90 days
Payload	5 to 1500 kilograms
Crew Size	0 to 3 men

MOBEV 3-30-1166

UNMANNED EXPLORATION

This illustration shows an operational layout of a vehicle being used in unmanned exploration.

An unmanned rover has four roles in lunar exploration:

1. Reconnaissance across zones of discontinuities or rapidly changing properties to obtain sufficient understanding so that a judgment can be made as to whether or not the zone is significant enough to commit a manned landing

2. Linear traverses at polar and backside areas where manned vehicles are not likely to be sent

3. Visual description and specific analyses of certain structural and morphological features which cannot be reached by man

4. Lateral extension of surface coverage of one or more measurements from the landing point of a stationary probe.

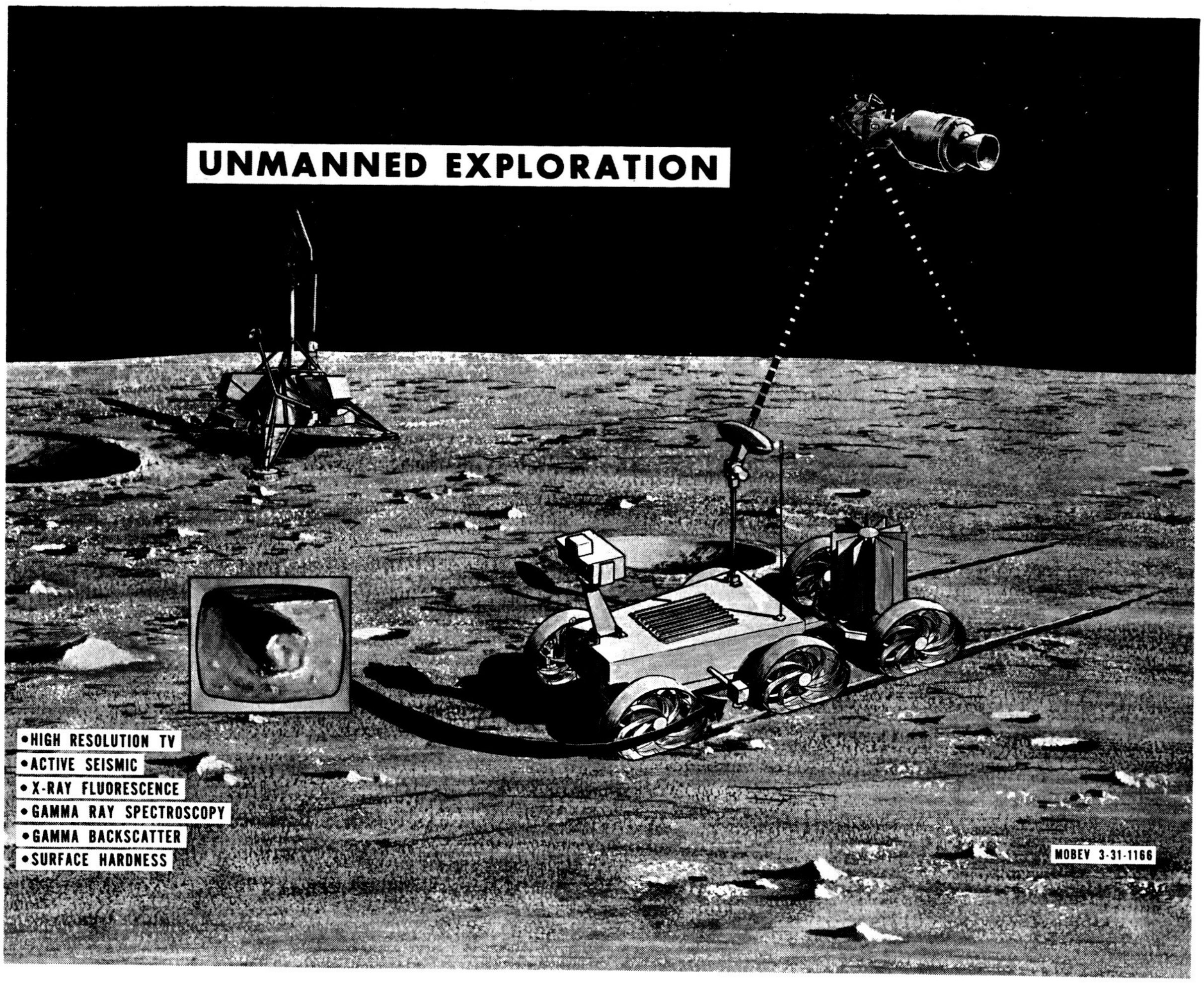
The measurements to be conducted can include the following:

1. Monoscopic, high-resolution (0. 1 mm), colar images of the near vicinity of the vehicle to provide a broad context on the five-scale surface geometry

2. Active seismic studies to obtain data on the subsurface configuration

3. X-ray fluorescence to obtain in situ analysis of the lethologic character of the surface material

4. Continuous analysis of materials properties by gamma-ray spectroscopy and gamma backscatter, and surface hardness.


UNMANNED EXPLORATION
•HIGH RESOLUTION TV
•ACTIVE SEISMIC
•X-RAY FLUORESCENCE
•GAMMA RAY SPECTROSCOPY
•GAMMA BACKSCATTER
•SURFACE HARDNESS
MOBEV 3-31-1166

UNMANNED EXPLORATION MISSIONS

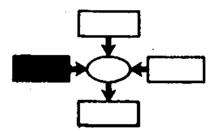
This illustration shows the nominal mission requirements set up for unmanned exploration. Three missions are postulated:

1. The R0AE mission was originally conceived for the Apollo site selection program. This vehicle is to be carried to the lunar surface by a Surveyor and be capable of traveling freely across the surface. The mission consists of measurements of lateral variation of surface and subsurface parameters and investigation of specific lunar structural and morphological problems which would require extreme landing accuracy for a stationary lander. The vehicle is to be operated in lunar day only over a total mission duration of 90 days. To minimize the number of earth stations to be used, the vehicle is operated for 8 hr/day maximum. The total range required is 40 km which provides for a statistical sampling of an area 3200 m around the landing point.

2. The R0CE mission utilizes a Surveyor probe from a lunar orbiting vehicle. The rover would operate in lunar day or night and have a total range capability of 200 km over a 90-day period. A wide variety of scientific instruments make up the 50-kg payload.

3. The R0DE mission is based upon the vehicle being delivered to the lunar surface with the LM-Shelter or a LM-Truck-Shelter and used during and after the manned mission to explore areas prior to committing a man, and to extend the data obtained during the manned mission to a much larger area. The vehicle should have a total range capability of about 800 km which may be used in a detailed, intensive survey pattern or on a linear traverse across a boundary area. The vehicle should have a mission duration of 90 days with vehicle usage of about 9 hr/day and a minimum of 50 kg payload capability.

UNMANNED EXPLORATION

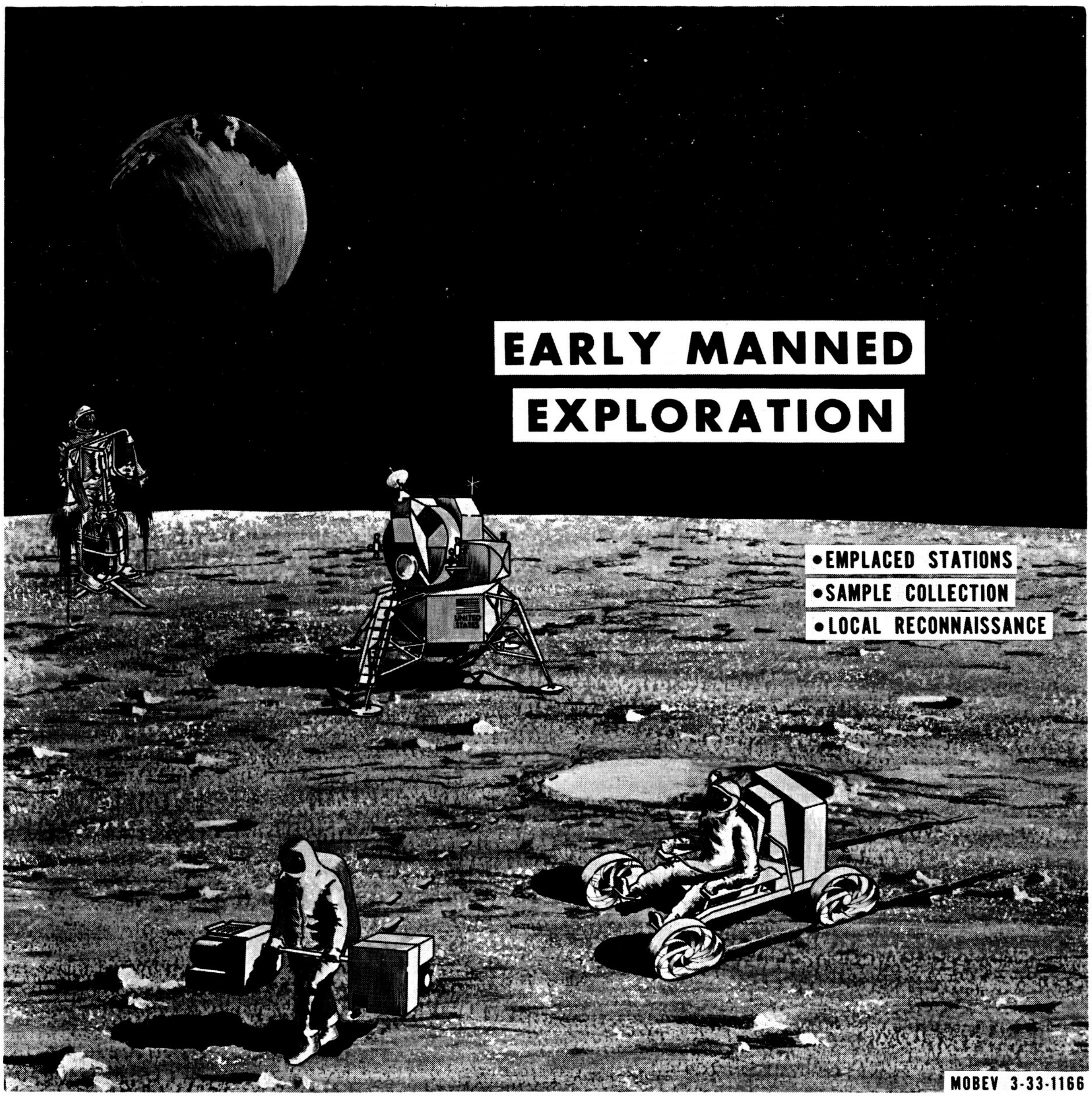


Mission	Range, km	Payload, kg	Duration, days
R0AE	40	4	90
R0CE	200	50	90
R0DE	800	50	90

MOBEV 3-32-1166

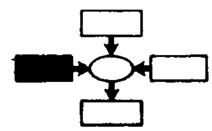
EARLY MANNED OPERATIONS

Early manned operations will utilize the basic Apollo LM or an augmented version of it. The augmented version is shown opposite with a small mobility unit. The mobility unit is dependent upon the shelter for recharge capability and can accommodate a single astronaut plus a small scientific payload. In addition to the reconnaissance capability the vehicle can be used as a "pack mule" by replacing the astronaut with additional payload (emplaced scientific station) and manually controlled by an astronaut walking alongside.


EARLY MANNED
EXPLORATION
•EMPLACED STATIONS
•SAMPLE COLLECTION
•LOCAL RECONNAISSANCE
MOBEV 3-33-1166

EARLY MANNED MISSIONS

Rovers and flyers can both be utilized in early manned operations. The chart shows a set of mission requirements in this category for both types of vehicles. R1AE and R1A(1)E are both small reconnaissance vehicle requirements with limited payload capability and short range and operating duration. They are the minimal manned mission requirements established in the study. R0BE is an astronaut assist vehicle requirement for cargo handling and deployment. F1A is a requirement for a unit for accessibility to difficult terrain or limited quick reconnaissance.



EARLY MANNED MISSIONS

Rovers (One-Man)

Mission	Range km	Payload kg	Duration hr
ROBE	14	75	6
R1AE	12	10	3
R1A(1)E	12	75	3

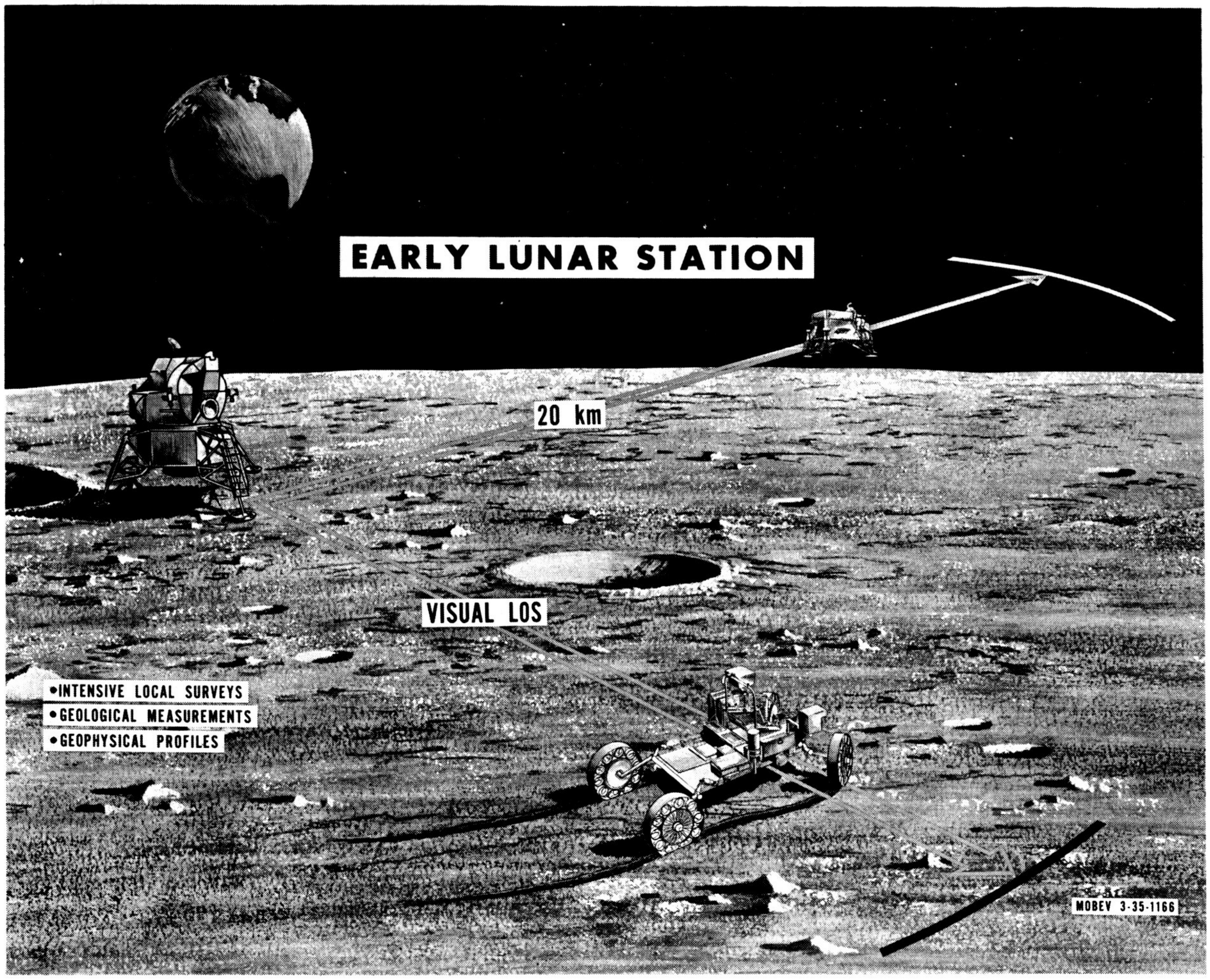
Flyers

Mission	Range km	Crew
F1A	8	1

MOBEV 3-34-1166

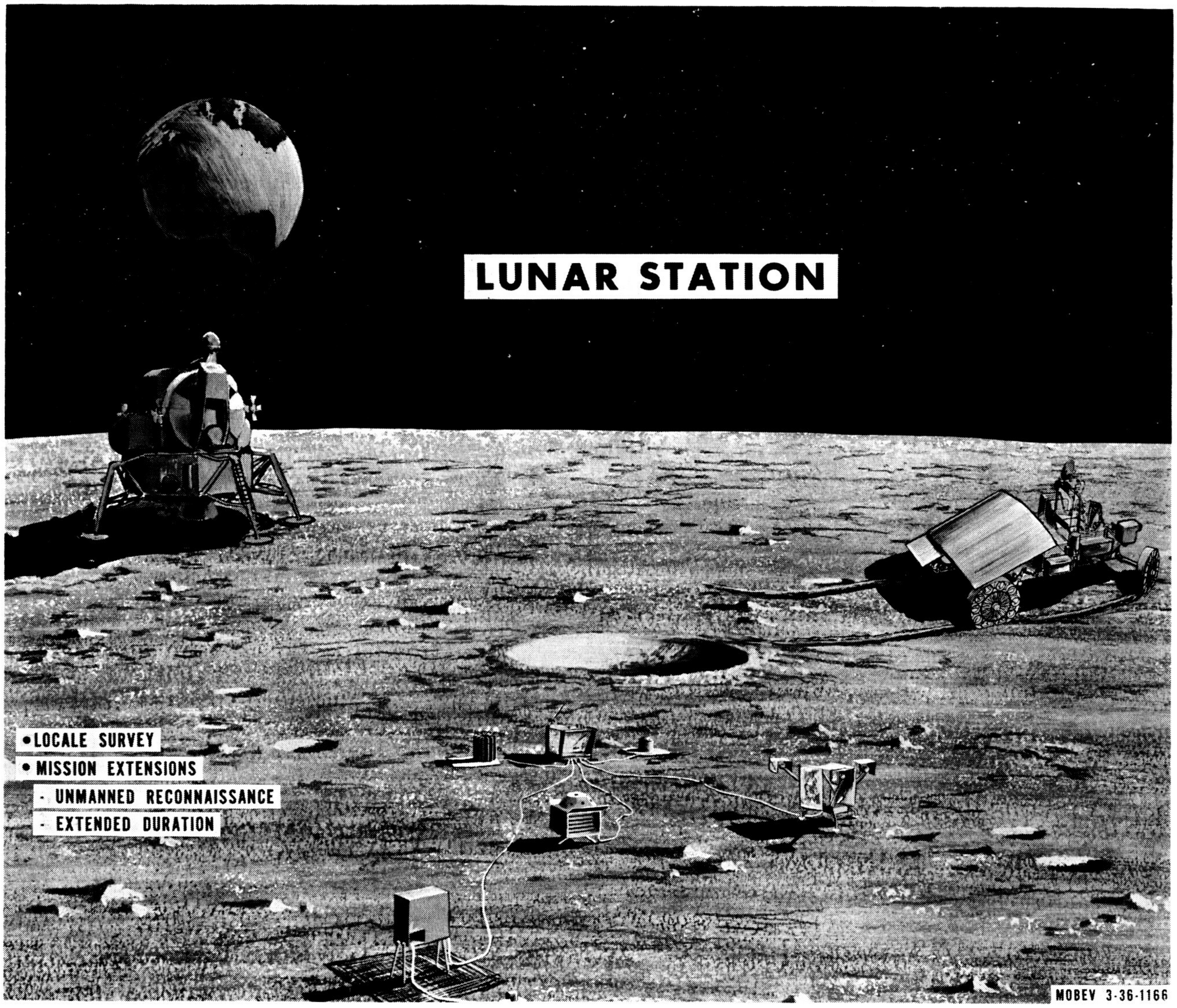
EARLY LUNAR STATION

An early lunar station using a LM-Shelter is shown. Vehicle operations can take place to a maximum radius of about 15 km with surface mobility and about 20 km with the flying unit The roving vehicle shown is completely shelter dependent, i. e., it requires a recharge source and thermal protection by the shelter. Missions in this category will generally be of 14-day duration; and vehicles will be open cabin type limited to a two-PLSS duration of six hours.


EARLY LUNAR STATION
20 km
VISUAL LOS
•INTENSIVE LOCAL SURVEYS
•GEOLOGICAL MEASUREMENTS
•GEOPHYSICAL PROFILES
MOBEV 3-35-1166

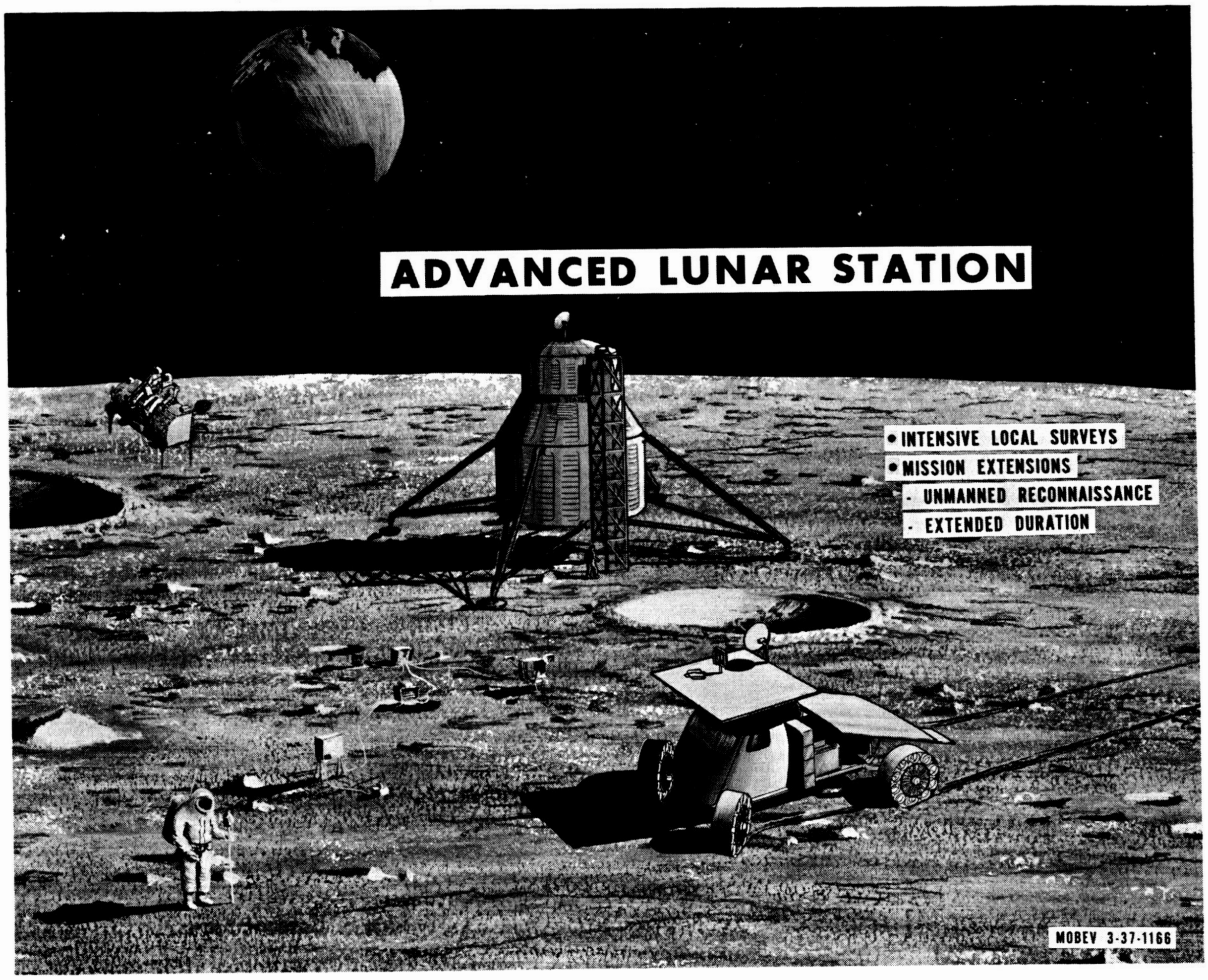
LUNAR STATION

This illustration shows another lunar station concept which includes a self-contained roving unit. Such a vehicle could be utilized prior, during, and after the manned mission in a remote mode to investigate dangerous terrain prior to committing a man, and to augment or extend the basic data obtained during the manned operation. The vehicle includes direct earth link communications and a self-contained power unit requiring no recharge source at the base station..


LUNAR STATION
•LOCALE SURVEY
• MISSION EXTENSIONS
- UNMANNED RECONNAISSANCE
- EXTENDED DURATION
MOBEV 3-36-1166

ADVANCED LUNAR STATION

As lunar exploration progresses, the sophistication of lunar station mission concepts will increase, allowing longer staytimes (over 30 days) and increased supporting payloads. This illustration shows an advanced lunar station concept consisting of a fixed shelter and a small roving vehicle with a cabin to provide life support for short-duration operation (up to 48 hr). This vehicle will allow operations to be performed at a radius exceeding 50 km from the fixed shelter and can make available greater scientific time on shorter traverses.

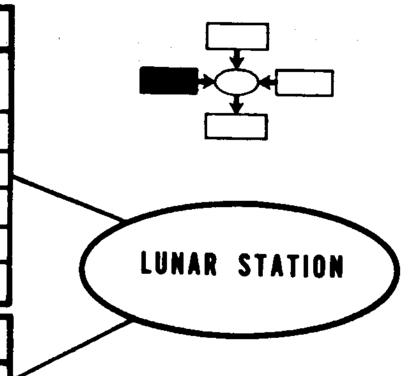

ADVANCED LUNAR STATION
• INTENSIVE LOCAL SURVEYS
• MISSION EXTENSIONS
- UNMANNED RECONNAISSANCE
- EXTENDED DURATION
MOBEV 3-37-1166

LUNAR STATION MISSIONS

This illustration shows the mission requirements which have been established for roving and flying vehicles applicable to lunar station exploration system concepts. The LSSM type missions, R1BE and R1B(1)E, while showing identical mission requirements parameters, are different in that R1B(1)E is to be independent of shelter support and capable of extended missions and remote operations. R1CE and R1DE are both advanced concepts requiring life support systems aboard the vehicle. R2AE, a two-man LSSM, is similar to R1BE with a payload-crew trade-off. The flyer missions shown are intended to provide capability for rescue from the roving vehicles or the lunar station as well as exploration capability. Both one- and two-man vehicles are applicable to this category of exploration. The F2E flyer mission is a return-to-orbit emergency provision for two men.

Rovers				
Mission	Range km	Payload kg	Duration hr	Crew
R1BE	30	320	6	1
R1B(1)E	30	320	6	1
R1CE	40	320	12	1
R1DE	125	320	48	1
R2AE	30	150	6	2

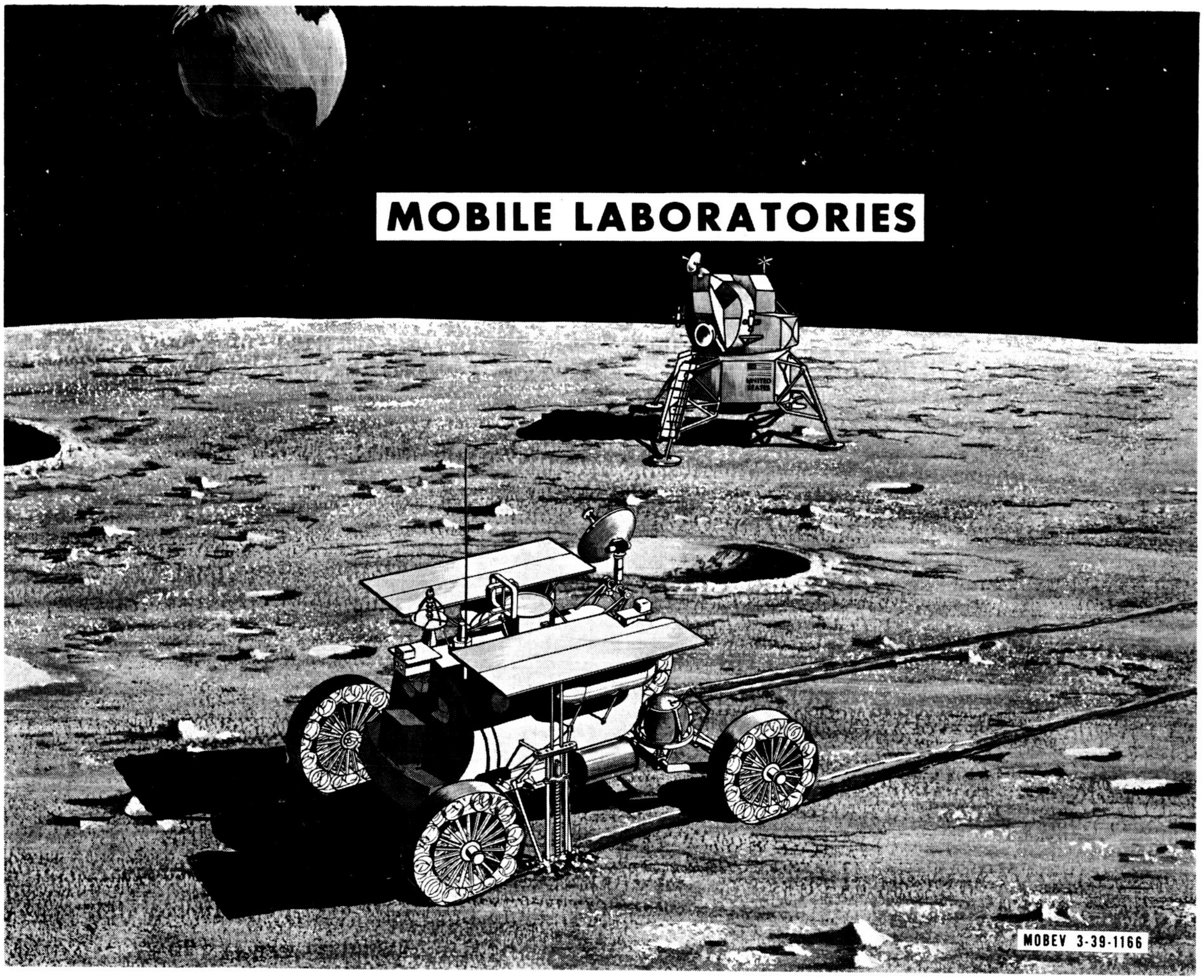
Flyers		
Mission	Range km	Crew
F1B	20	1
F1C	14	1
F2A	20	2
F2B	50	2
F2E	LOR	2



MOBEV 3-38-1166

MOBILE LABORATORIES

To obtain data about the moon on a regional geological scale (100 km x 100 km), a mobile laboratory (shown opposite) which combines the reconnaissance and laboratory functions with field work capability included is used. A basic mission which obtains regional data in the Kepler-Encke region has been proposed and is shown as the Modified Beattie Selenological Traverse consisting of a 14-day duration, one and one-half figure eight loops in an 80-km radius about the landing point. The ALSS Scientific Mission Support Studies analyzed the detailed science to be conducted and the basic time utilization for the mission. The mission equipment is delivered by a LM-Truck system and the crew via a LM-Taxi.


MOBILE LABORATORIES
MOBEV 3-39-1166

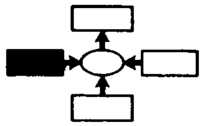
MOBILE LABORATORY MISSIONS

The chart shows the mission requirements for mobile laboratories and flying vehicles used in support of the roving operations. R2BE, R2CE, and R2DE are all two-man missions, while R3AE and R3CE are three-man missions. The missions range from eight days (a mobile laboratory used in support of extended fixed-base operations) to 28 days. Scientific experiments to be conducted include gravity and magnetic surveys, seismic profiling, and subsurface geological studies including drilling. The payload for this type of work would be 320 kg as outlined in the Scientific Mission Support Studies. In the case of R3AE, the payload was increased to 700 kg in accordance with the increased staytime and crew size. The flying vehicles shown in the previous mission requirements slides can also be used in conjunction with the mobile laboratory vehicles.

MOBILE LABORATORIES

Flyers		
Mission	Range km	Crew
F2C	100	2
F2D	200	2
F3A	50	3
F3B	200	3

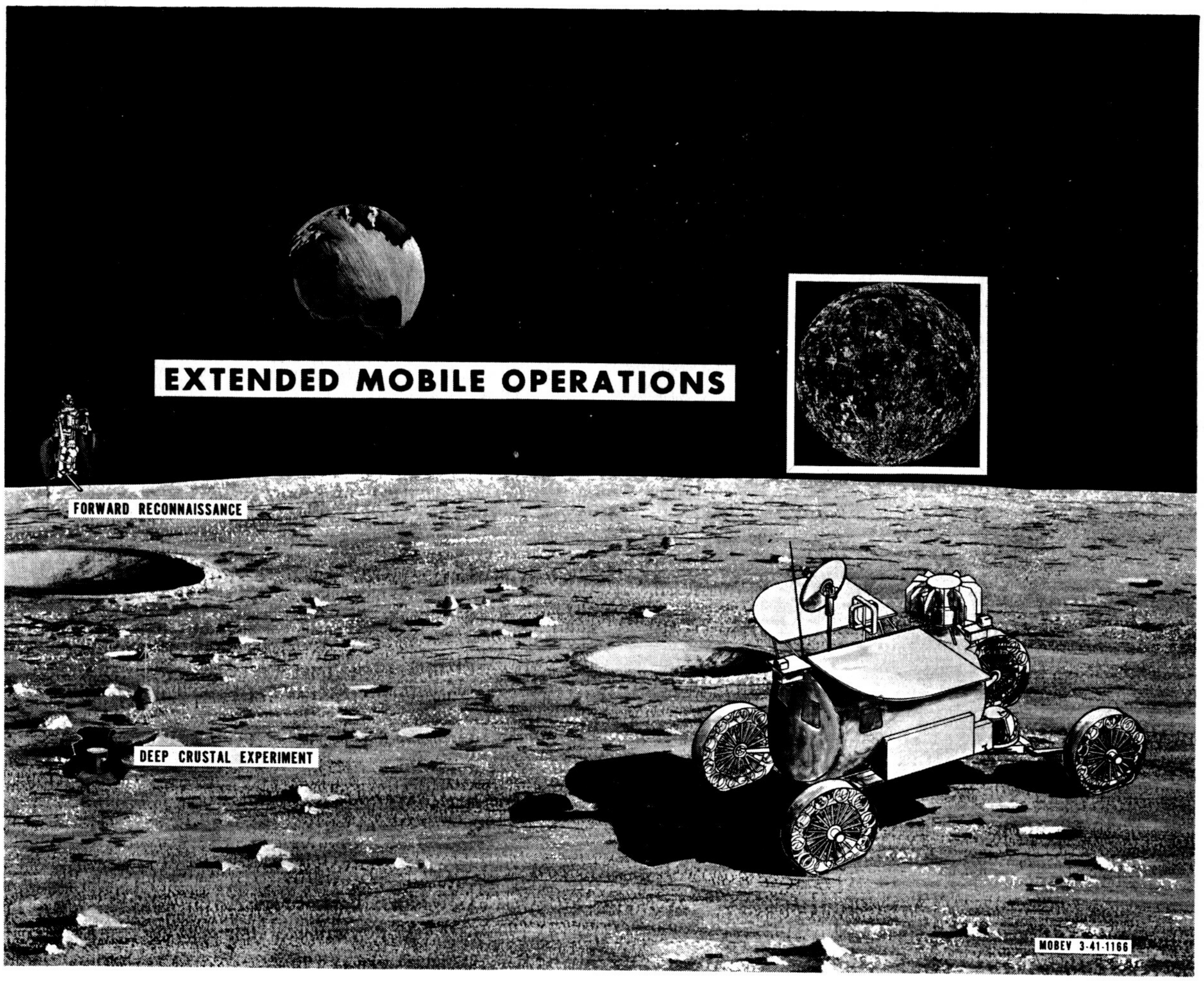
Rovers				
Mission	Range km	Payload kg	Duration Days	Crew
R2BE	250	320	8	2
R2CE	400	320	14	2
R3CE	400	320	14	3
R2DE	800	320	28	2
R3AE	800	700	28	3



MOBEV 3-40-1166

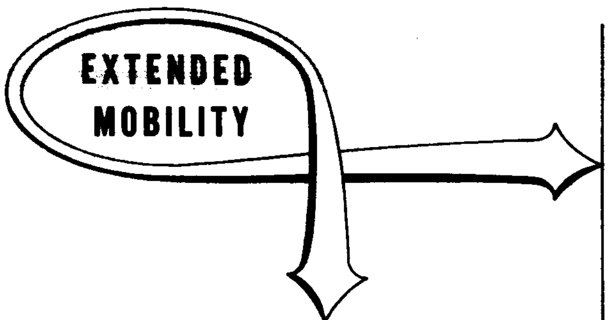
EXTENDED MOBILE OPERATIONS

The MIMOSA scientific programs have identified geophysical profiles or "paths" extending across regional geologic barriers for ranges in excess of 3000 km. To obtain such ranges and provide sufficient scientific time, a three-man, 90-day duration mission is shown. The operational concept shown here depicts the deployment of seismic charges for deep crustal studies. A small flying vehicle for forward reconnaissance activities is also shown.


EXTENDED MOBILE OPERATIONS
FORWARD RECONNAISSANCE
DEEP CRUSTAL EXPERIMENT
MOBEV 3-41-1166

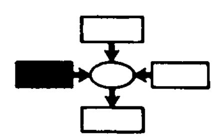
EXTENDED MOBILITY MISSIONS

The illustration shows the mission requirements which have been identified for the long-range traverse roving vehicles and flying vehicles which might be used in support or rescue operations from such missions. Three roving vehicle missions have been identified. R3BE and R3DE are three-man vehicles of 42 days and 90 days duration, respectively. 90 days is the longest mission duration which has been considered for mobility systems. R4AE is a four man vehicle of 56 days duration and is the largest crew size considered in the study. A nominal payload of 1500 kg consisting of geological/geophysical reconnaissance instruments and emplaced stations was established for each of these missions. The flyer missions shown provide very long range and return-to-orbit capability for a three-man crew. Four-man flying vehicle missions were not considered in the study.



Flyers		
Mission	Range km	Crew
F3C	400	3
F3D	800	3
F3E	LOR	3

Rovers			
Mission	Range km	Payload kg	Duration Days
R3BE	1600	1500	42
R3DE	3500	1500	90



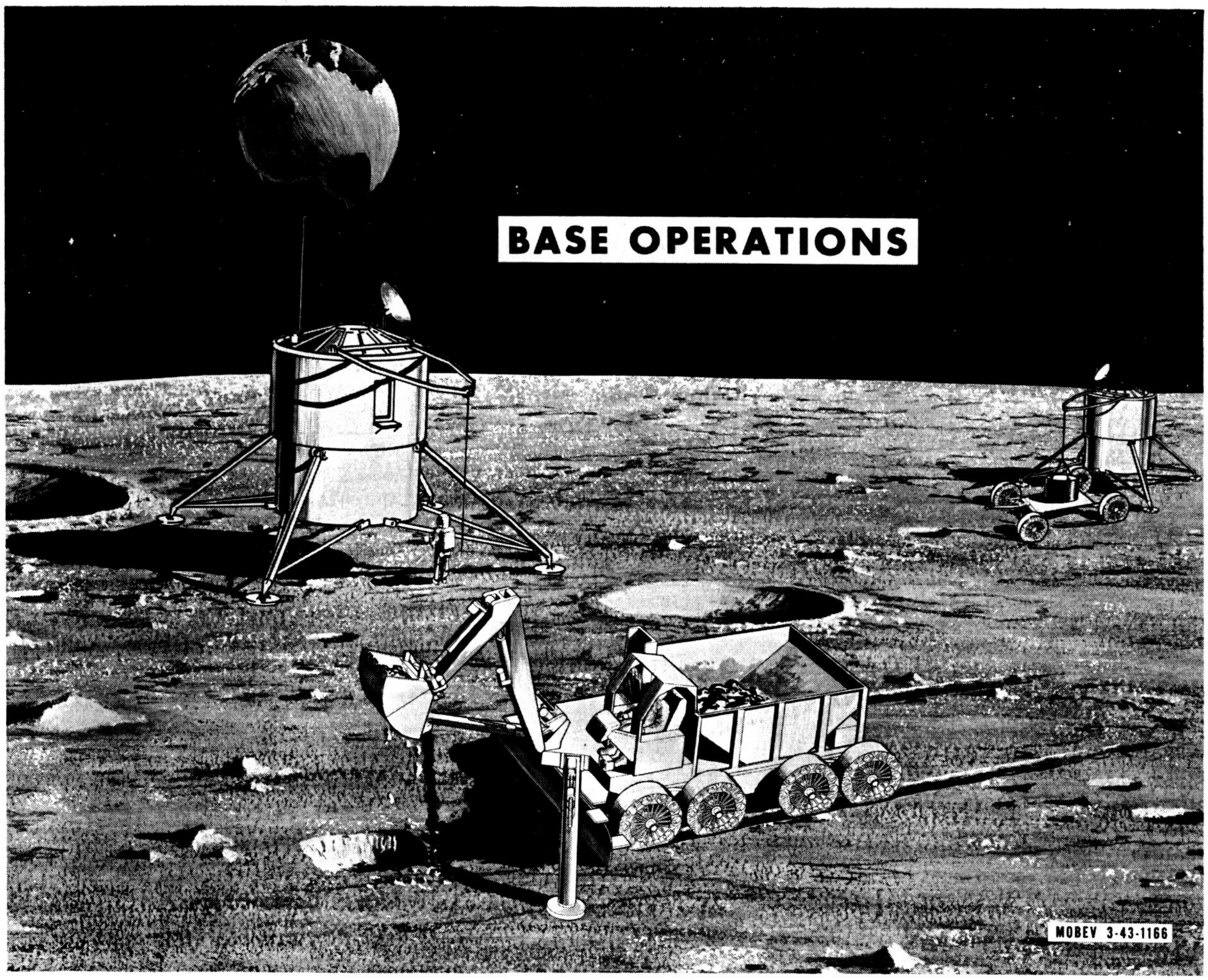
MOBEV 3-42-1166

BASE OPERATIONS

A lunar base is a shelter complex which serves as a place from which multiple lunar missions are to be performed. This base is expected to have an operational period which is greater than the expected staytime of a single crew. Therefore, the operational duration of the base is designated as being from long term to semipermanent. A shelter such as the LM around which exploratory operations are performed is not considered as a lunar base since it is of short operational duration and is not subject to reactivation. Only one set of lunar base concepts has been investigated in detail to date; namely, LESA.

The illustration shows a base deployment operation; namely, the transport and deployment of a buried nuclear reactor power supply.

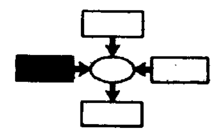
A variety of vehicular tasks must be performed for the deployment and operation of a lunar base. These include cargo handling and transport, personnel transport, and surface modifications. Considerations of each of these tasks has led to the definition of the mission requirements spectrum.


BASE OPERATIONS
MOBEV 3-43-1166

LUNAR BASES

The slide shows the mission requirements as postulated for base support. These have been grouped into three categories: prime movers, trailers, and special-purpose vehicles. The prime movers are derivatives of exploration roving vehicles. For the construction function, many of the requirements are satisfied by appendages to the prime movers of the exploration vehicles. However, for surface grading and leveling tasks, a new, special-purpose prime mover concept is required. This is a high-powered prime mover, identified as requirement R1CB. The requirement is for a highly tractive vehicle with a bulldozer grader blade, backhoe, clam-shell bucket, towing hitch, and winch attachments. The crew consists of one man located in a protective shelter utilizing the PLSS. The duty cycle is anticipated to be 6 hr/day.

Trailer requirements exist primarily for the material-handling and cargo transport function. A technique for developing trailer systems to meet the base support requirements is to employ the mobility system of prime movers, retaining the wheel and drive mechanisms, suspension, and chassis.



LUNAR BASES

Prime Movers			
Mission	Payload kg	Range/Trip km	Crew
R1AB	320	35	1
R1BB	320	40-125	1
R2BB	320	100-400	2

Trailers	
Requirement	Cargo kg
R0AB	650
R0BB	2500
R0CB	6500

Special Purpose	
R1CB	
Range/Trip	10 km
Payload	2500 kg
Duration	6 hr
+ Appendages	
+ Soil Hopper	

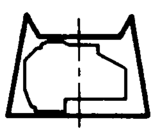
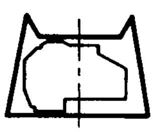
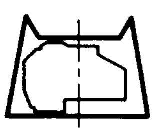
MOBEV 3-44-1166

DELIVERY SYSTEM CONCEPTS–1

The primary constraint on the design of the roving vehicles is the delivery system. Two factors are considered in the assignment of a delivery system to missions and vehicles, and the number of possible combinations are thus limited. The first factor is adequate delivery system payload mass capacity. In many vehicle-delivery system combinations the "mass margin" appears to be high and yet when the potential use of the "mass margin" for scientific and backup vehicles is anticipated, the advantage of keeping vehicle weight to a minimum is essential. While it is necessary to keep vehicle weight as low as practical, it is also worthy to assure that an adequate design margin exists.

The second factor considered in the selection of vehicle-delivery system combinations is the geometric restraints established by the payload envelope. These restraints often require additional complexity in the vehicle design to provide a "folding" capability to increase the vehicle packaging density. In some cases the "folding" capability has been retained even though the geometric restraints do not seem to justify this packaging technique. However, as in the case of mass, the potential use of the available packaging volume for supplementary payloads will justify this vehicle packaging approach. Ten delivery systems were considered in the study. Five of these, the Surveyor Landers (both direct and lunar-orbit launched) and the Apollo LM, Augmented LM, and LM-Shelter are shown on this illustration.

DELIVERY SYSTEM CONCEPTS - 1

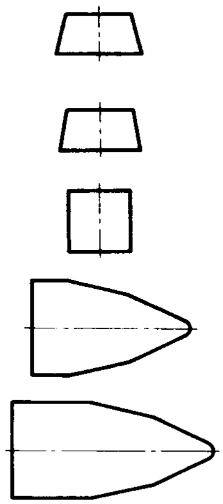
	Surveyor Direct Probe	68 kg
	Surveyor Lunar Orbit	175 kg
	LM - Apollo	114 kg
	LM - Augmented	600 kg
	LM - Shelter	1880 kg

MOBEV 3-45-1166

DELIVERY SYSTEM CONCEPTS—2

This illustration shows the five larger delivery systems considered in the study. The first three are LM derivatives and consider both cryogenic and storable propellants as well as lunar orbit rendezvous and direct launch modes. The last two are lunar logistics vehicle concepts used in conjunction with various Saturn upratings.

DELIVERY SYSTEM CONCEPTS - 2

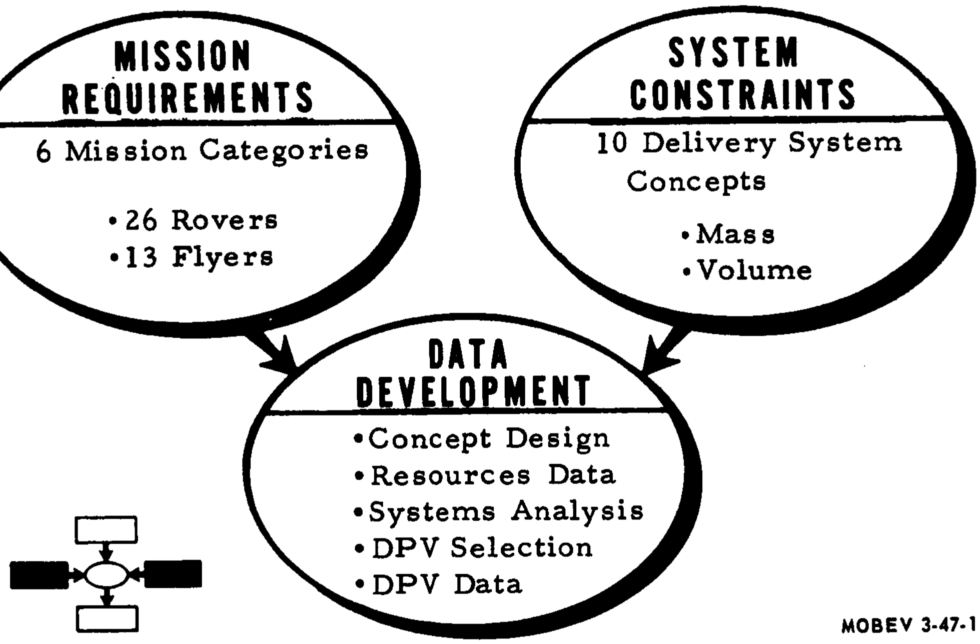


LM - Truck (LOR)	4260 kg
LM - Truck (LOR-CRYO)	5440 kg
LM - Truck (Direct)	8900 kg
LLV - 1	12,000 kg
LLV - 2	25, 400 kg

MOBEV 3-46-1166

MOBILITY REQUIREMENTS AND CONSTRAINTS SUMMARY

The mission analysis studies have resulted in the formulation of 26 roving and 13 flying vehicle mission requirements in six categories associated with exploration system concepts. In addition, the mass and volume constraints of 10 delivery system concepts were identified for use in the vehicle concepting effort. These requirements and constraints have been used in the vehicle data development, which consists of the conceptual designs and resource requirements, system analysis and Design Point Vehicle selection, and data development for the Design Point Vehicles for the final data book and the methodology inventory.



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MOBILITY TECHNICAL AND RESOURCES DATA

MOBEV

Final Presentation

MOBEV 3-48-1166

SPEAKER: WALT CROSMER

MOBILITY TECHNICAL AND RESOURCES DATA

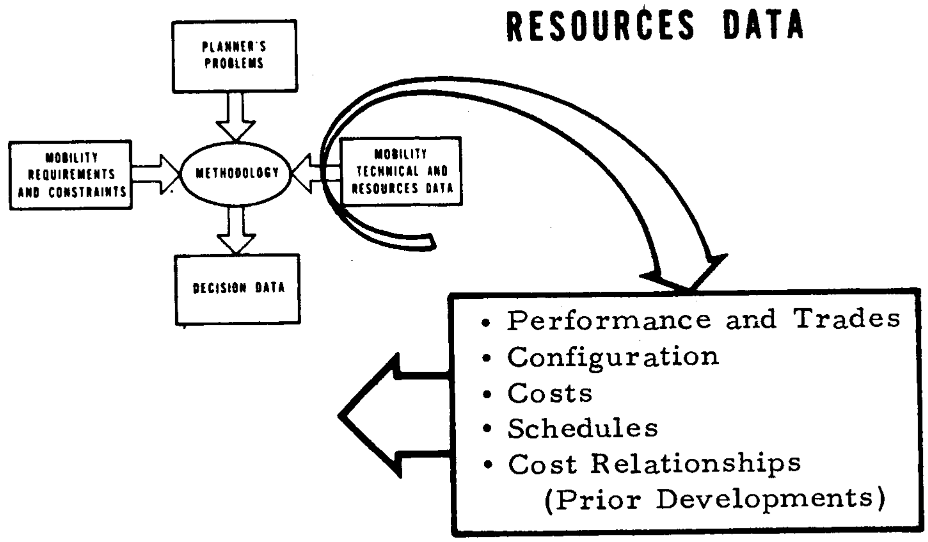
From the mobility requirements and constraints established early in the MOBEV program, the system design of the mobility systems was conducted.

System design occurred in two discrete periods during the MOBEV study. The first time was aimed at configuring vehicles to meet the initial mission requirements spectrum. A total of 18 exploration and 8 base support roving vehicles, and 13 flying vehicles were studied and documented with their resources requirements in the initial data book (BSR-1350). Four of the vehicle concepts presented (MOLAB, MOLEM, MOCOM, and MOCAN) were altnerates for a single-mission requirement.

Systems analysis studies involving vehicle subsystem commonality analysis, subsystem parametrics, system sensitivity analysis, and Design Point Vehicle recommendations and selection were conducted. Vehicle commonality matrixes were developed for all major subsystems contained in each vehicle concept, and recommended alternate subsystem combinations were identified. This included functional definition as well as identification of major hardware components. To determine the performance limits for each vehicle, sensitivity anayses were conducted which included generation of the subsystem parametric data and definition of scaling factors. Utilizing the sensitivity and comparative data, unique vehicles were identified and specific recommendations made with respect to subsystem hardware to be included in the Design Point Vehicle spectrum.

The second period of system design concerned itself with the detailed definition of the Design Point Vehicles (DPVs), which were classified as either primary or secondary. The resource requirements (cost and schedule data) for these vehicles were also defined as well as cost and schedule savings effects of prior development. These data have been documented in the final data book and are also contained in the data tapes supplied with the evolution methodology.

MOBILITY TECHNICAL AND RESOURCES DATA



MOBEV 3-24-1166

SYSTEM DESIGN APPROACH

Illustrated is a flow diagram of the design approach to the surface vehicle systems. Initially, mission analyses were conducted to provide mission requirements resulting in definition of a mobility spectrum. This spectrum was compared against existing concepts, and mobility gaps requiring further effort identified.

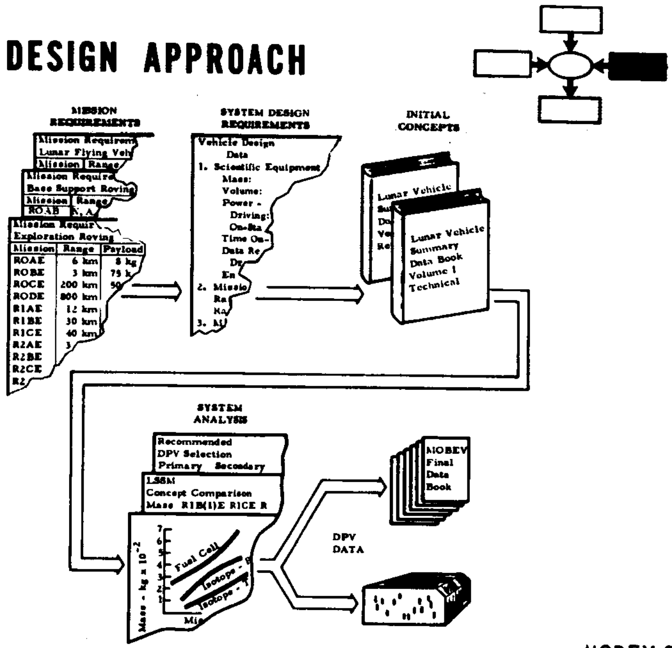
As a result of having identified the existing mobility gaps, a number of conceptual design studies were conducted to define the complete mobility systems spectrum. New concepts were formulated and design and resources analyses conducted.

An initial concepts data summary covering the complete spectrum of mobility system concepts was prepared for use in MIMOSA.

Systems analysis studies were then carried out consisting of three main efforts: (1) vehicle subsystem commonality analysis, (2) system sensitivity analysis, and (3) Design Point Vehicle recommendations. Utilizing sensitivity and comparative data, unique vehicles were identified and specific recommendations made with respect to subsystem hardware to be included in the final Design Point Vehicle summary.

These analyses led to the selection of recommended Design Point Vehicles. These DPV data are given in the DPV Data Book, and included in the methodology library of data.

SYSTEM DESIGN APPROACH



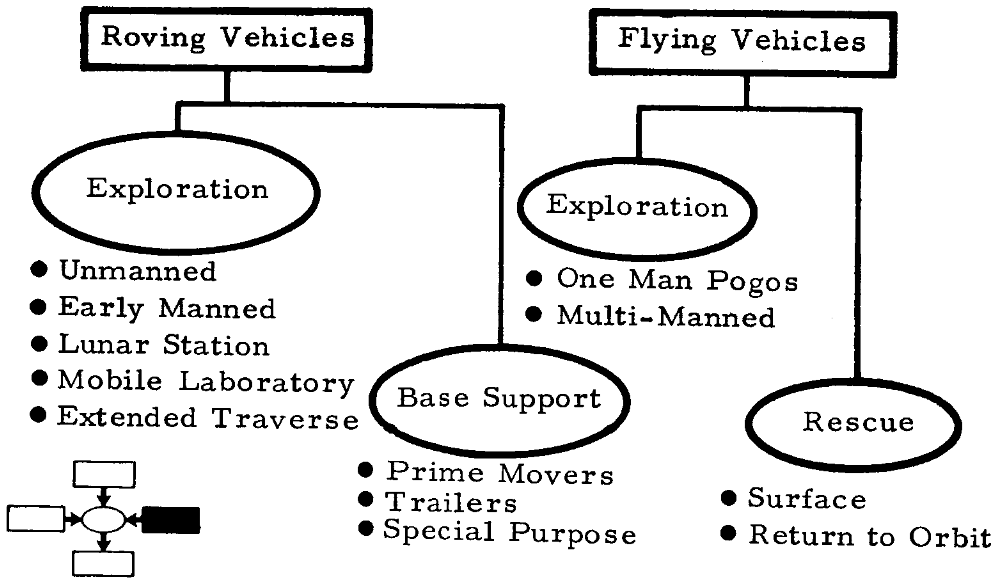
MOBEV 3-49-1166

MOBILITY SPECTRUM

The slide shows the mobility spectrum by its various functional and exploration categories. Lunar surface mobility systems may be either flying or roving types. Roving vehicles are used either for exploration or base support. Five exploration system concepts have been identified and used in the classification of vehicle utilization. Base support vehicles have been identified as prime movers, trailers, or special purpose for surface modification tasks.

Flying vehicles may be used for exploration or rescue. Exploration vehicles are either the single crew, POGO-type configuration, or are multi-manned vehicles capable of transporting cargo in addition to crew members. Rescue vehicles consist of surface to surface or return-to-orbit vehicles for rescue of stranded astronauts.

MOBILITY SPECTRUM



MOBEV 3-49a-1166

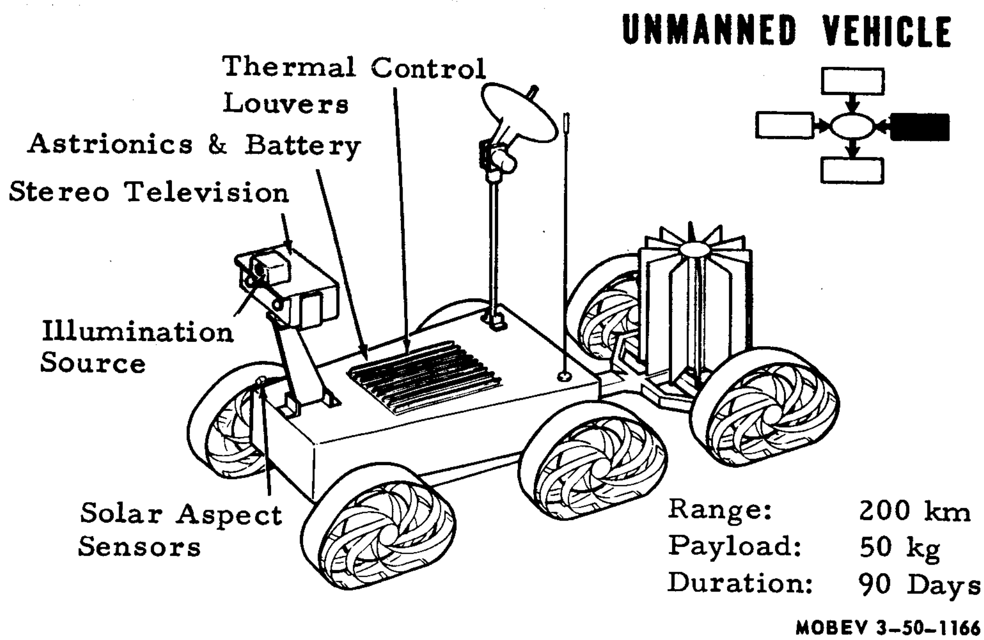
UNMANNED VEHICLE (R0CE)

The Remote Unmanned Traverser, R0CE, is an unmanned, remote-controlled exploration vehicle which can operate anywhere on the lunar surface. It carries 50 kg of scientific payload on a mission of 200 km in range and 90 days in duration, and has an average driving speed of 1 km/hr. The mission commences after remote deployment of the R0CE from the delivery vehicle. Each 24-hr period thereafter is comprised of an operational phase and a standby phase. The operational phase consists of 2.2 hr of driving and 4.8 hr of scientific on-station time. The standby phase consists of the remaining 17.0 hr, during which time the batteries are recharged by the RTG.

The power subsystem consists of a 56-w RTG and AgCd batteries. The batteries provide the additional power (90 w average) required during the operational phase, and are recharged during the standby period.

The mobility subsystem consists of a four-wheel chassis with a two-wheel trailer attachment. All six wheels are of the spiral-spoked flexible variety, and each is individually powered by a motor and transmission. Ackermann steering is accomplished by means of two actuators.

The astrionics subsystem includes communication, navigation, and illumination equipment. The communication equipment operates in the S-band and provides for direct earth transmission of telemetry and TV signals, and reception of command data from earth. The S-band directional antenna is steered on command from earth. When operating at the poles or on the back side of the moon, communications with earth is via moon satellite relay. The principal navigation components are the two-axis inclinometer, sun sensors, and odometer. The illumination equipment is used as an aid in lunar night operations.


UNMANNED VEHICLE
Thermal Control
Louvers
Astrionics & Battery
Stereo Television
Illumination
Source
Solar Aspect
Sensors
Range: 200 km
Payload: 50 kg
Duration: 90 Days
MOBEV 3-50-1166

VEHICLE TECHNICAL DATA ASSEMBLY

This illustration portrays some of the technical data available on all vehicles. The data book format for each vehicle is as follows:

A. Configuration

1. Description - This includes a hardware tree to the subsystem level, as well as a subsystem power and energy summary.

2. Drawings - Included are external configurations, and, where applicable, internal configurations and installation configurations.

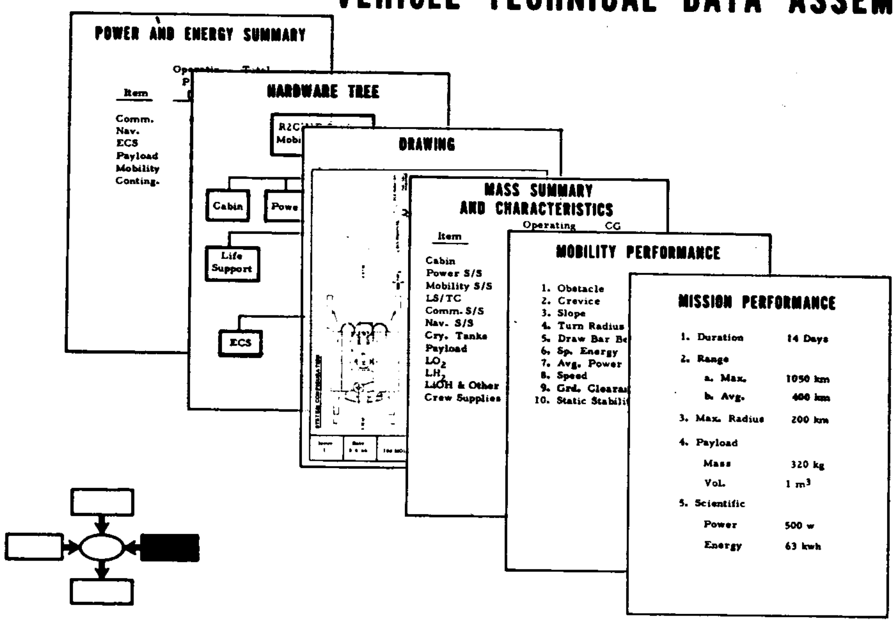
3. Mass Summary and Characteristics - A system and subsystem mass breakdown is provided together with center of gravity locations.

B. Mobility Performance - A tabulation of vehicle mobility capability is given including obstacle, crevice, and slope negotiability, speed, and specific energy.

C. Mission Performance - This section gives a description of the vehicle mission capability and includes: mission range and radius; payload weight, volume, power, energy and data handling requirements; and driving and on-station times.

D. Subsystems Definition - Each subsystem is described individually in terms of design criteria and constraints, performance, functional diagrams, hardware trees, mass summaries, and individual component descriptions.

VEHICLE TECHNICAL DATA ASSEMBLY



MOBEV 3-51-1166

VEHICLE RESOURCES DATA ASSEMBLY

This illustration portrays some of the resources data available on all vehicles. The resources data format for each vehicle is as follows:

1. Basic Cost Breakdown - This section includes non-recurring costs and recurring costs. These include breakdowns for such items as mockups, test articles, and delivered GSE. Also included are other costs such as support developments and brick and mortar facilities.

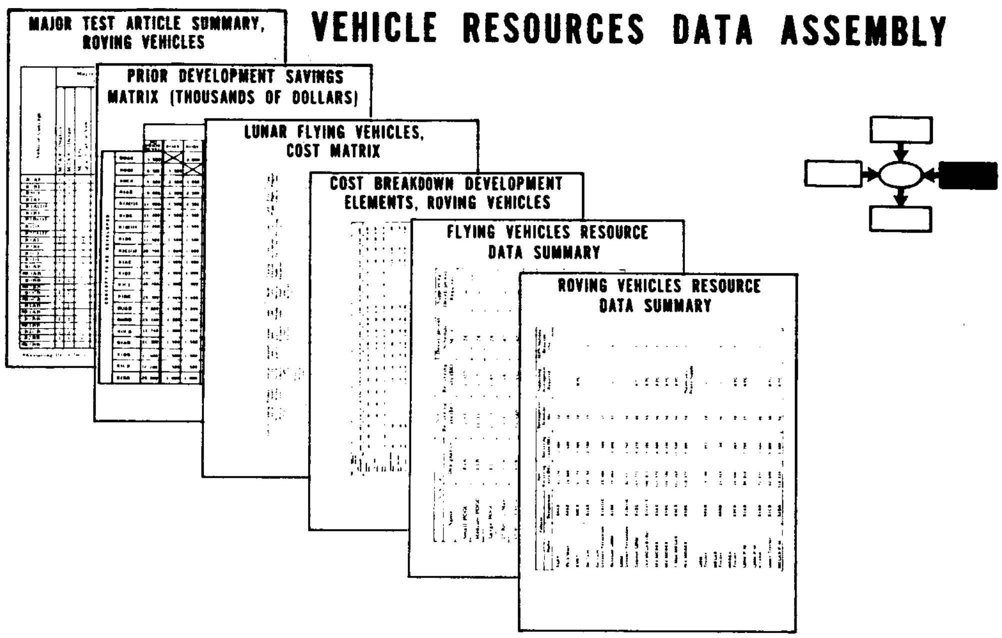
2. Development Schedule - A quarterly schedule is given showing the various control points, development functions, and hardware deliveries required to complete the first flight-qualified vehicle.

3. Funding Schedule - Shown in 6-month increments are the non-recurring costs required for vehicle system development, facilities, and the first flight vehicle.

4. Learning Curve - Total recurring costs are given as a function of flight units, showing the cost savings realized on succeeding flight units.

5. Facility Requirements - Shown are facilities required of both the Government and contractor. Included are such items as floor space at various installations, and equipment requirements (e. g., vibration laboratory, vacuum chambers, and antenna test range).

VEHICLE RESOURCES DATA ASSEMBLY



MOBEV 3-52-1166

EARLY MANNED VEHICLE (R1A(1)E)

The Go-Cart, R1A(1)E, is a manned exploration vehicle designed primarily to enhance the astronaut's mobility and carrying capability, and thereby increase his range of operations. The vehicle can also be used solely to carry payload by replacing the astronaut with his weight in additional payload. The astronaut then controls the vehicle through use of a hand-held manual control box.

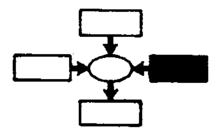
The R1A(1)E is compatible with delivery by a LM-Shelter or an Augmented-LM and has the capability for a three-month lunar storage. Thermal control during the storage period is provided by the delivery vehicle. The vehicle is designed for multi-sorties of 12 km in range and three hours in duration. Average speed in the manned mode is 5 km/hr with a payload of 75 kg.

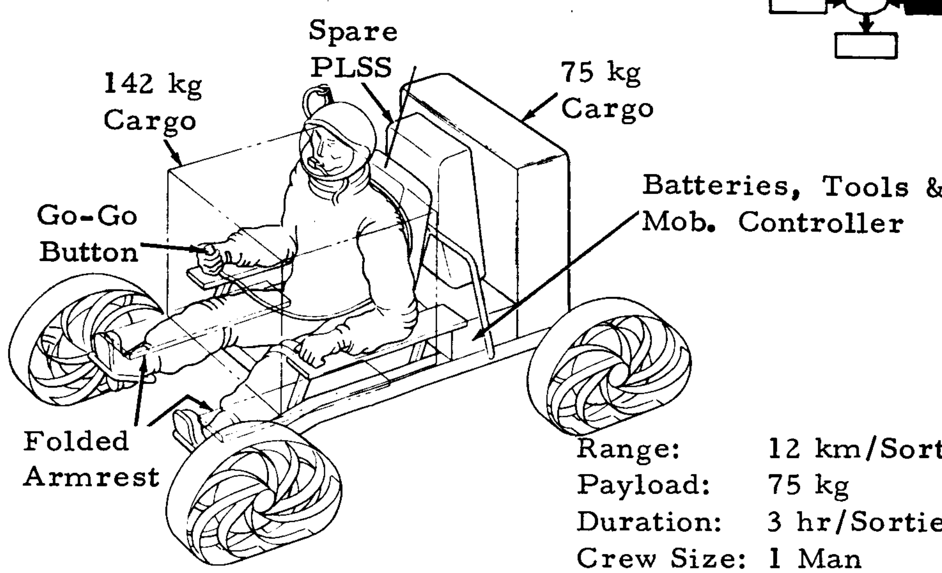
The crew station consists of a driver's seat, restraints, and mobility controls. The driver's seat folds for use as an additional payload storage area; the mobility controller can also be used by the astronaut while off the vehicle.

The power subsystem consists of AgZn batteries with a total usable energy capability of 1.3 kwh. Recharge of the batteries is accomplished from the LM-Shelter.

The mobility subsystem consists of four individually driven and suspended metal-elastic wheels. Electrical actuators are used to provide steering.

EARLY MANNED VEHICLE





Range:	12 km/Sortie
Payload:	75 kg
Duration:	3 hr/Sortie
Crew Size:	1 Man

MOBEV 3-53-1166

UNMANNED AND EARLY MANNED CONCEPT SUMMARY

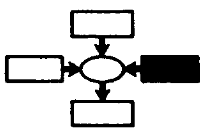
The design data for unmanned remote controlled vehicles R0AE and R0CE are summarized on this illustration, together with the design data for the early manned concepts R0BE, R1AE, and R1A(1)E. The R0AE and R0CE are similar, having the same mission duration, and utilizing an RTG for primary power. However, the R0CE carries considerably more scientific equipment, can operate during both lunar day and night, and can travel three times the distance.

The R0BE and R1A(1)E are also similar in function. Both are used by an ambulating astronaut, increasing his range and equipment-carrying capability. However, the R1A(1)E can also, by offloading some scientific payload, transport the astronaut himself, giving additional speed and range.

The R1AE is similar to the R1A(1)E in that both carry the astronaut and a payload, but the R1AE's payload is limited to 10 kg. The vehicle is unique, however, since it can be delivered by the Apollo Lunar Module.

R0CE and R1A(1)E have been designated as primary DPVs; R0AE, R0BE, and R1AE are secondary DPVs.

UNMANNED AND EARLY MANNED CONCEPTS SUMMARY



	Unmanned Vehicles		Early Manned Vehicles		
	SLRV ROAE	RUNT ROCE	PACK MULE ROBE	GO-CART R1AE	MINI-LSSM R1A(1)E
Delivered Mass (kg)	62.1	148	66	107	133
Scientific Payload (kg)	4.0	50	75	10	75
Crew Supplied Mass (kg)	N. A.	N. A.	29	29	29
Total Operating Mass (kg)	62.1	148	170	288	379
Number of Sorties/Range (km)	-/72	-/200	5/15	20/240	12/144
Average Maximum Speed (km/hr)	0.4	1.0	4.0	5.0	5.0
Obstacle (cm)	30	27	27	20	33
Development Cost ($M)	41.3	51.2	14.8	24.1	28.4
Development Time (mos.)	32	34	30	33	33

MOBEV 3-54-1166

LUNAR STATION VEHICLE (R1B(1)E)

The Greater Versatility LSSM, R1B(1)E, is an exploration vehicle designed for both manned and unmanned operation. The vehicle is landed aboard a LM-Shelter and is designed for a 90-day storage period after arrival on the lunar surface. Thermal control during this period is provided by the vehicle on-board RTG.

The manned portion of this mission consists of twelve 30-km sorties during a 14-day period. However, prior to and/or after this manned mode, the vehicle is capable of unmanned remote-controlled exploration. The six-month life of the 650-w RTG limits the time period during which these missions can be accomplished, but degraded versions can be undertaken after the six-month period. The vehicle carries 320 kg of scientific equipment with an average speed of 8 km/hr while manned. The unmanned average speed during the remote controlled mode is 2 km/hr.

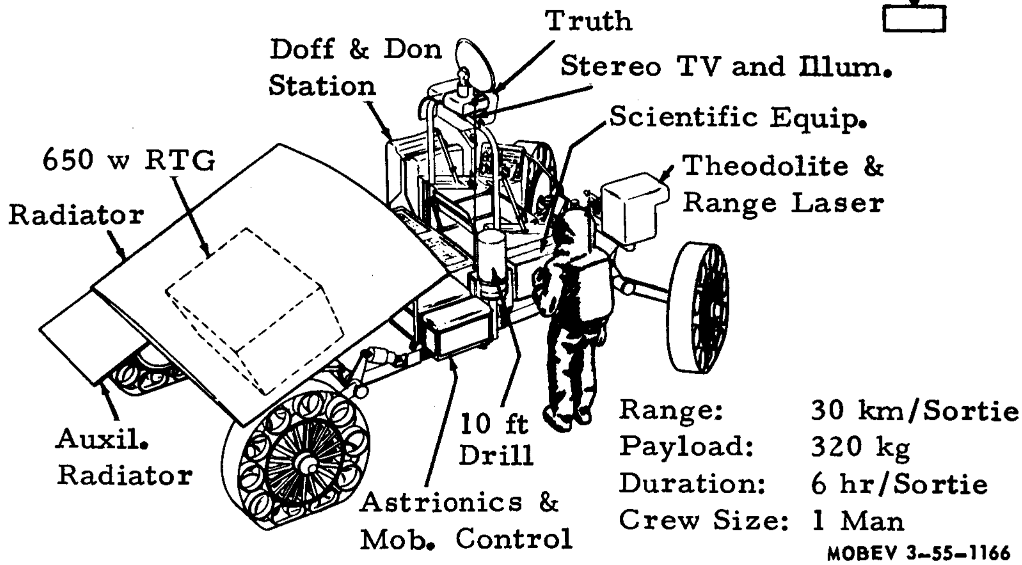
The crew station accommodates the astronaut in a seated position. The seat is centered under the roll bar and access to the seat is from the front, using the folding steps. Controls and displays are integrated into the crew station structural assembly.

The power subsystem consists of a 650-w RTG, plus an AgCd battery. The battery provides for peak power demands above the RTG output, and is recharged by the RTG during periods of low power requirements. In the unmanned mode the vehicle is capable of continuous operation; in the manned mode it can operate for six hours, and then requires ten hours to recharge the battery.

The mobility subsystem consists of four individually driven and suspended metal-elastic wheels. The drive motors and transmissions are hub mounted. Steering is accomplished by actuators in the front wheels.

The astrionics subsystem consists of communication, navigation, television, and illumination equipments. The communications equipment provides for remote control of the vehicle from earth, and communication between the vehicle and earth (S-band), the LM-Shelter (VHF), and another EVA astronaut (VHF). The navigation equipment provides a dead-reckoning capability with an accuracy of 1 km after traveling 50 km. The television equipment includes a television camera providing a forward-looking stereo pair. The illumination equipment is provided as an aid in lunar night use of the vehicle.

LUNAR STATION VEHICLE



LUNAR STATION VEHICLE (R1DE)

The Cabined LSSM, R1DE, is a manned exploration vehicle designed to provide a shirt-sleeve (open spacesuit faceplate) environment. The vehicle is delivered by a LM-Truck and is designed for up to six months of lunar storage prior to commencement of the mission. Prior to the crew's arrival, the vehicle is remotely unloaded and driven to the site of the astronaut's landing. The vehicle's mission is to provide three 48-hr sorties, and three 8-hr sorties during the 14 days the crew is on the moon. The range per sortie is 125 km per 48-hr sortie, and 40 km per 8-hr sortie. The vehicle carries a 320 kg scientific payload, and has an average speed of 8 km/hr.

The cabin is a basic semimonocoque pressure shell. A large front-viewing window is located in the cabin full-length hinged door, and two side windows are also provided to enhance astronaut visibility. The astronaut seat incorporates a restraint system. The basic control and display pedestal is attached to the exit door permitting unobstructed entry and exit from the cabin.

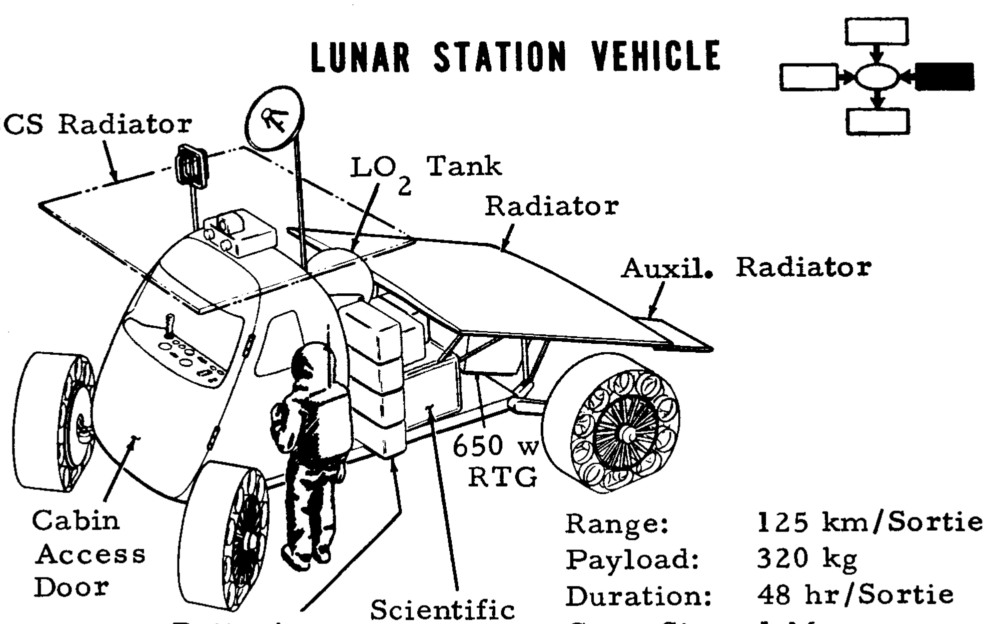
The power subsystem consists of a 650-w RTG and an AgCd battery. The battery provides for peak power demands above the RTG output, and is recharged by the RTG during periods of low power requirements. Thermal control of the vehicle during the lunar storage phase is provided by the on-board RTG. As shown earlier, the power subsystem selection is based on LSSM vehicle evolutions, packaging considerations, and extended capability.

The mobility subsystem consists of four individually driven and suspended metal-elastic wheels. The drive motors and transmissions are hub-mounted. Steering is accomplished by actuators in the front wheels.

The major elements of the life support subsystem are the crew provisions and the Environmental Control System (ECS). The crew provisions include equipment and expendables associated with the personal needs of the astronaut. The ECS provides pressurization, atmosphere control, cabin and suit temperature control, humidity control, contaminant control, and water management.

The astrionics subsystem is comprised of the communication, navigation, television, and illumination equipments. The communications equipment provides for S-band communications between the vehicle and earth, and for local lunar communications at VHF between the vehicle and the shelter, EVA astronaut, or other lunar terminals. The navigation equipment provides dead-reckoning computation with an accuracy of 1 km after traveling 50 km. The television equipment includes a television camera providing a forward-looking stereo pair.

LUNAR STATION VEHICLE



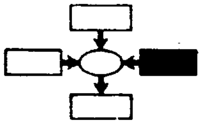
Range: 125 km/Sortie
Payload: 320 kg
Duration: 48 hr/Sortie
Crew Size: 1 Man

MOBEV 3-56-1166

LUNAR STATION CONCEPTS SUMMARY

Shown are the design data for lunar station concepts R1BE, R1A(1)E, and R1DE. These vehicles are all of the LSSM type, and all have been designated as primary DPVs. The R1BE is a baseline concept, providing only for astronaut and payload transportation. The R1B(1)E is the greater versatility concept, providing all the functions of the R1BE plus full communications (S-band as well as VHF), remote control capability, and navigation equipment. The R1DE provides all the functions and capabilities of the R1B(1)E as well as providing a cabin (vented suit) atmosphere and increased range and duration.

LUNAR STATION CONCEPTS SUMMARY



	Lunar Station Vehicles (LSSMs)		
	Baseline	Greater Vers.	Cabin
	R1BE	R1B(1)E	R1DE
Delivered Mass (kg)	664	1071	1724
Scientific Payload (kg)	320	320	320
Crew Supplied Mass (kg)	58	58	69
Total Operating Mass (kg)	864	1272	1935
Number of Sorties/Range (km)	14/420	22/660	3/500
Average Maximum Speed (km/hr)	8	8	8
Obstacle (cm)	62	62	62
Development Cost ($M)	35.1	82.5	164
Development Time (Mos.)	33	36	40

MOBEV 3-57-1166

MOBILE LABORATORY VEHICLE (R2C(1)E)

The R2C(1)E is a manned mobile laboratory (MOLAB) used for exploration of the moon. The MOLAB provides complete life support capabilities for its two-man crew during a 14-day, 400-km mission. A seven-day life support contingency, beyond the basic 14 days, is also included in the design. The MOLAB carries 320 kg of scientific payload, and has an average driving speed of 10 km/hr. The MOLAB is delivered to the moon by a LM-Truck, and is capable of being stored for as long as six months before commencing its mission. Prior to the crew's arrival, the MOLAB is remotely unloaded and driven to the site of the crew's landing. The 14-day mission commences with the arrival of the crew.

The MOLAB power subsystem consists of two advanced P&W fuel cells, as well as the small RTG and battery. Each fuel cell assembly is rated at 3.25 kw maximum continuous power. The fuel cells are activated before the MOLAB is unloaded. Included in the oxygen used for the fuel cells is the metabolic oxygen used by the life support subsystem.

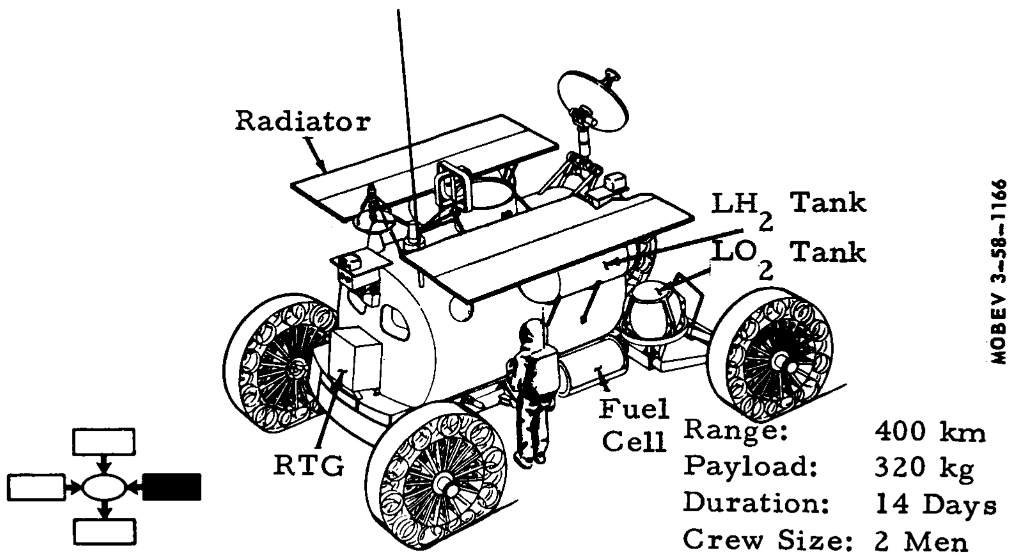
The cabin subsystem includes a horizontally oriented cylindrical cabin containing an airlock, five external viewports, and the crew stations. Controls and displays are provided at the two-position driving "cockpit," the scientific station, and the aft emergency driving station located in the airlock. Meteoroid protection is provided by the cabin structure.

The mobility subsystem consists of four metal-elastic wheels individually powered by a motor and transmission, steering actuators located in the front wheel hubs, and suspension and deployment mechanisms. The mobility subsystem requires about 5.5 kw of maximum continuous power to traverse the 50/50 ELMS.

The life support/thermal control subsystem consists of the crew provisions and the Environmental Control System (ECS). The crew provisions include equipment and expendables associated with the personal needs of the astronauts. The ECS provides pressurization, atmosphere control, cabin and suit temperature control, humidity control, contaminant control, and water management.

The astrionics subsystem is comprised of communication, navigation, and TV equipments. The communications equipment provides for S-band communications between the vehicle and earth, and for local lunar communications at VHF between the MOLAB and the Command Module, EVA astronaut, or other lunar terminals. The navigation equipment utilizes two navigation techniques: a position fix mode, and a dead-reckoning mode. The television equipment includes a television camera providing a forward-looking stereo pair; a single, monoptic camera for rear viewing; and three cameras for cabin internal viewing and monitoring.

MOBILE LABORATORY VEHICLE

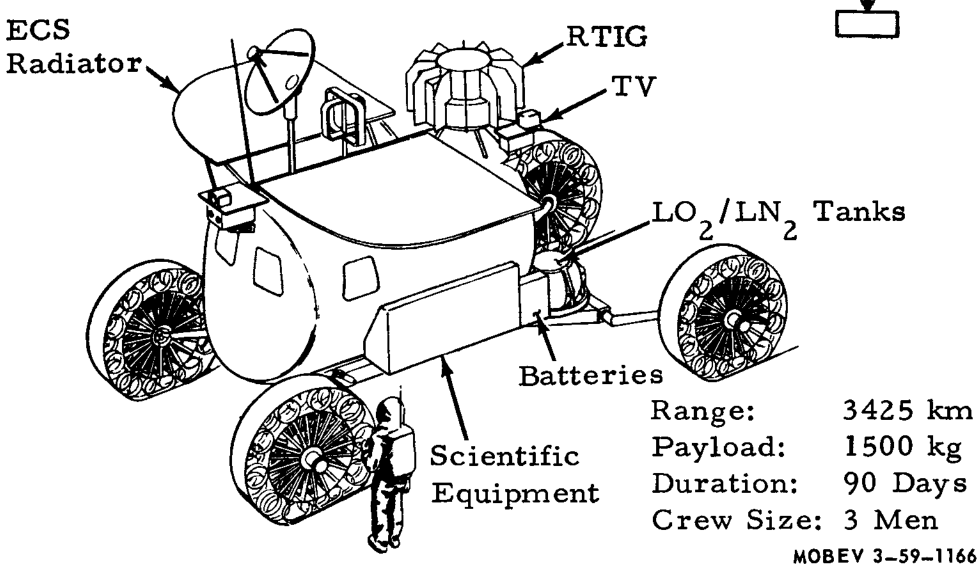


EXTENDED TRAVERSE VEHICLE (R3DE)

The 90Day MOBEX, R3DE is a manned mobile laboratory used for exploration of the moon. The vehicle provides complete life support capabilities for its 3-man crew during a 90-day, 3425-km mission. The vehicle carries 1500 kg of scientific payload, and has an average driving speed of 10 km/hr. The R3DE is delivered to the moon by an LLV, and is capable of being stored for as long as six months before commencing its mission. Prior to the crew's arrival, the vehicle is remotely unloaded and driven to the site of the crew's landing. The 90-day mission commences with the arrival of the crew.

The R3DE power subsystem consists of an isotopic power supply as well as an AgCd battery. The isotopic power supply is rated at 3.45 kw. A battery is used during peak power demands above the isotopic output and is recharged during periods of low power requirements. The cabin subsystem includes a horizontally oriented cylindrical cabin containing an airlock, five external viewports, and the crew stations. Controls and displays are provided at the two-position driving "cockpit," the scientific station, and the aft emergency driving station located in the airlock. Meteoroid protection is provided by the cabin structure. The mobility subsystem consists of four metal-elastic wheels individually powered by a motor and transmission, steering actuators located in the front wheel hubs, and suspension and deployment mechanisms. The life support/thermal control subsystem consists of the crew provisions and the Environmental Control System (ECS). The crew provisions include equipment and expendables associated with the personal needs of the astronauts. The ECS provides pressurization, atmosphere control, cabin and suit temperature control, humidity control, contaminant control, and water management. The astrionics subsystem comprises the communications, navigation, TV, and illumination equipments. The communications equipment provides for S-band communications between the vehicle and earth, and for local lunar communications at VHF between the vehicle and the command module, EVA astronaut, or other lunar terminals. The navigation equipment utilizes two navigation techniques: a position fix mode and a dead-reckoning computation. The TV equipment includes a TV camera providing a forward-looking stereo pair; a single, monoptic camera for rear viewing; and three cameras for cabin internal viewing and monitoring. Illumination equipment is provided to aid in lunar-night operations.

EXTENDED TRAVERSE VEHICLE

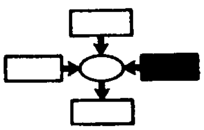


MOBILE LABORATORY AND EXTENDED TRAVERSE CONCEPTS SUMMARY (R2CE, R3AE, R3BE, R3CE, R3DE)

The MOLAB (R2C(1)E and R3CE) design data are summarized on this illustration, as well as design data for the MOBEX concepts (R3AE, R3BE, and R3DE). All five of these vehicles provide mobility, living quarters, and work area for the astronauts on the lunar surface. The R2C(1)E and R3CE designs and characteristics are similar except for the addition of an astronaut to the R3CE Concept, thus increasing the scientific man-hours available on the mission. The R3AE, R3BE, and R3CE give increasingly larger payload, range, and duration capabilities.

The R2C(1)E, R3BE, and R3DE have been designated as primary DPVs, R3AE and R3CE are secondary DPVs.

MOBILE LABORATORY & EXTENDED TRAVERSE CONCEPTS SUMMARY



	MOLAB		MOBEX		
	2 Man	3 Man	28 Day	42 Day	90 Day
	R2C(1)E	R3CE	R3AE	R3BE	R3DE
Delivered Mass (kg)	2975	3231	4909	6923	6930
Scientific Payload (kg)	320	320	700	1500	1500
Crew Supplied Mass (kg)	139	169	222	286	988
Total Operating Mass (kg)	3398	3826	5557	7646	8344
Range (km)	400	400	800	1600	3425
Average Maximum Speed (km/hr)	10	10	10	10	10
Obstacle (m)	1.1	1.1	1.1	1.1	1.1
Development Cost ($M)	307	311	324	326	318
Development Time (mos.)	54	56	56	58	58

MOBEV 3-60-1166

BASE SUPPORT VEHICLE—SPECIAL PURPOSE (R1CB)

The R1CB is a manned lunar tractor which provides base support capability in terms of earth moving, towing, and general utility within close proximity of the base. To obtain maximum draw bar pull, approximately 1800 kg of ballast (lunar soil) must be placed in the vehicle hopper. When the ballast is no longer required, or if the vehicle is used for earth moving, doors in the bottom of the hopper can be opened, providing variable flow dumping capability. The available energy permits bulldozing or backhoeing during the entire sortie duration. The R1CB has an average no-load speed of 2.5 km/hr.

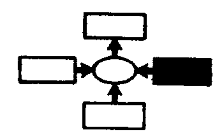
The crew station provided on this vehicle consists of a seat, restraints, and an open cabin with a protective windshield. The cabin/windshield pivots upward to permit astronaut entry.

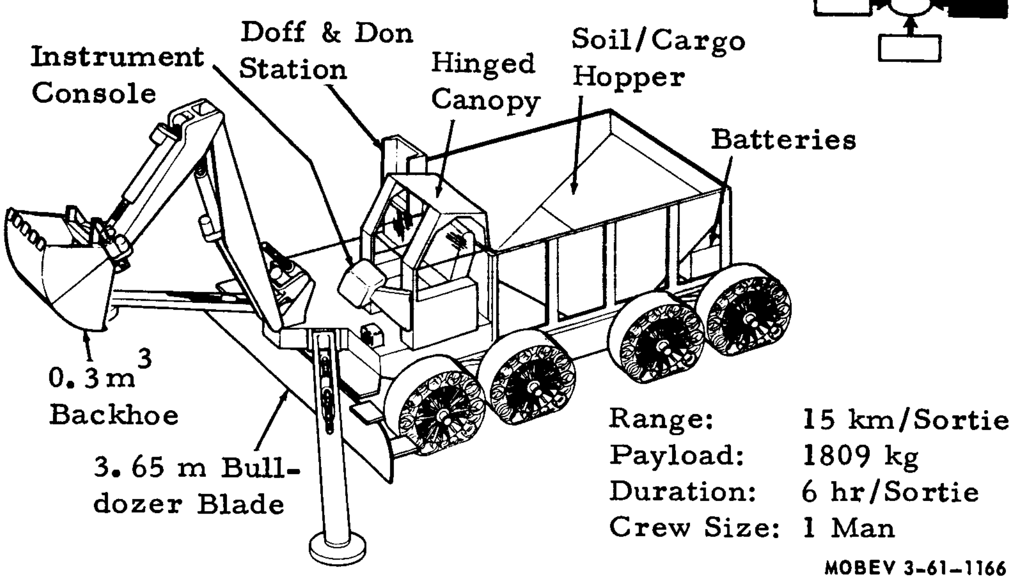
The power subsystem consists of rechargeable AgCd batteries, with a total available energy per charge of 24 kwh. Recharge is from a shelter or other external source.

The mobility subsystem consists of four pairs of metal-elastic wheels, each pair mounted on a bogie. Each of the eight wheels is individually powered by a motor and transmission. Steering is accomplished by varying motor rpm to allow scuff steering.

The vehicle appendages include a bulldozing blade, backhoe, trailer hitch, stabilization outriggers, and power winch. The bulldozing blade has a capacity of approximately 1.1 cu m, with a blade penetration of 0.25 m. Blade pitch angle and height control is accomplished by electrical linear actuators. The backhoe consists of a boom, dipper stick, and a 0.3 cu m bucket. The bucket can be used in a digging mode or clam shell mode, and has a maximum digging depth of 4.25 m.

BASE SUPPORT VEHICLE-SPECIAL PURPOSE

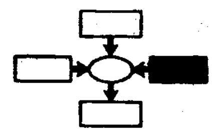


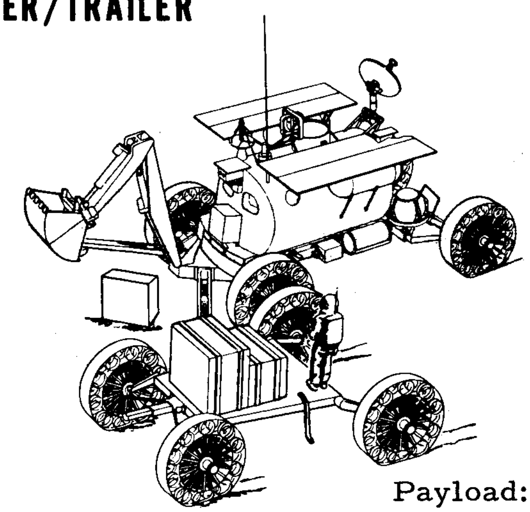


BASE SUPPORT VEHICLE—PRIME MOVER/TRAILER (R0BB)

The R0BB trailer concept provides base support capability in terms of cargo transportation within close proximity to the base. This trailer is a derivative of the R2C(1)E exploration vehicle design, and consists of only the R2C(1)E mobility subsystem minus the power steering equipment. Structural stiffeners and a flat bed deck have been added to the modified mobility subsystem to provide the cargo-carrying capability. A tow bar has also been added which provides steering by means of mechanical linkages. Power for the individual wheel drive motors is provided by the prime mover subsystem by means of a cable.

BASE SUPPORT VEHICLE-PRIME MOVER/TRAILER





Payload: 2798 kg

MOBEV 3-62-1166

BASE SUPPORT CONCEPTS SUMMARY

The base support concepts include trailers (R0AB, R0BB, and R0CB), prime movers (R1AB, R1BB, and R2BB), and a newly designed special-purpose prime mover (R1CB). The tasks required of the vehicles are: personnel transport, material handling and transportation (both horizontal and vertical), and surface modification and construction.

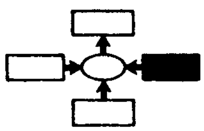
Requirements for the functions of personnel transport and material handling are satisfied by the prime mover vehicle concepts. For the construction function, appendages are added to the prime movers. For surface grading and leveling the R1CB is provided. Material transportation is provided by the trailer concepts.

All trailers and four of the prime movers are derivatives of exploration vehicles. The following table shows these relationships.

Base Support Concept	Derivative of Exploration Vehicle
R0AB, R1AB	R1B(1)E
R0BB, R2BB	R2C(1)E
R0CB	R3BE
R1BB	R1DE

Only R1CB has been designated as a primary DPV.

BASE SUPPORT CONCEPTS SUMMARY



	Base Support Vehicles						
	Trailers			Prime Movers			Special Purpose
	LSSM	MOLAB	MOBEX	LSSM	Cabin LSSM	MOLAB	Tractor
	R0AB	R0BB	R0CB	R1AB	R1BB	R2BB	R1CB
Delivered Mass (kg)	285	600	1205	752	1404	2655	2530
Payload (kg)	987	2798	6441	300	300	290	1809
Crew Supplied Mass (kg)	N. A.	N. A.	N. A.	58	69	139	58
Total Operating Mass (kg)	1272	3398	7646	1272	1935	3398	4539
Average Maximum Speed (km/hr)	N. A.	N. A.	N. A.	8	8	10	2.5
Obstacle (cm)	62	110	110	62	62	110	50
Development Cost ($M)	15.0	23.0	24.4	89.8	171	314	62.6
Development Time (Mos.)	28	30	30	33	40	54	38

MOBEV 3-63-1166

LFV CONFIGURATIONS

The flyers investigated fall into three types: (1) one-man pogos, (2) multi-man surface-to-surface vehicles, and (3) multi-man return-to-orbit vehicles. One of each type have been selected as primary DPVs. These are the F1B, F2B, and F2E concepts.

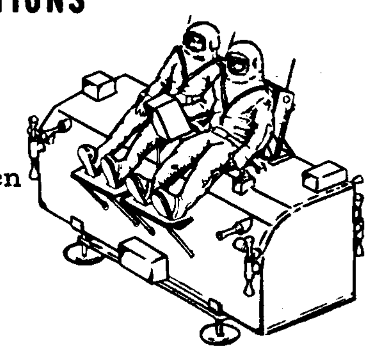
The one-man flying vehicle, F1B, relies on manual control obtained by thruster gimballing for pitch and roll, and jetavators for yaw. Communication is limited to the PLSS VHF, line of sight, voice system. Navigation and guidance is done visually with aids such as maps and a sextant to determine initial flight direction.

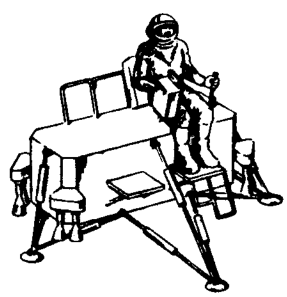
The multi-man surface-to-surface vehicle, F2B, uses differential throttling of the lift thrusters. Eight thrusters are used to provide engine out capability and provide an initial lunar thrust to weight ratio of 3. Two thrusters are mounted at the corners of the body in a slightly canted position to provide yaw control. An active three-axis attitude control system is provided. Continuous communications with the lunar base or roving vehicle during exploration are provided by an S-band system integrated with the PLSS system. Multiple landing capability is provided by reusable friction devices for landing energy absorption. A strap-down inertial guidance system provides the required guidance accuracy.

The return to orbit vehicle, F2E, is provided with six degree of freedom control for rendezvous as well as normal attitude control. Four main lift engines are used for boost and midcourse corrections and positive explusion tanks are provided. Line of sight communications with the orbiting CSM are provided by the PLSS VHF system with the addition of an amplifier to increase the range. The navigation and guidance system is the same as the surface-to-surface vehicle with the addition of a rendezvous transponder.

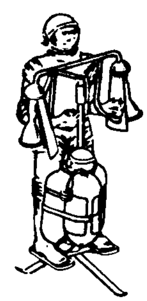
LFV CONFIGURATIONS

F2E
Range: LOR
Crew Size: 2 Men





F2B
Range: 50 km
Crew Size: 2 Men



F1B
Range: 20 km
Crew Size: 1 Man

MOBEV 3-64-1166

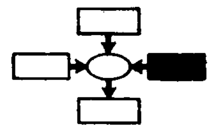
LFV CONCEPT SUMMARY—1

The MOBEV matrix of flying vehicles includes 13 design points which together fulfill mission requirements that were postulated early in the program. The vehicles are identical with corresponding vehicles in the MIMOSA matrix. The vehicles are of three general types as shown in these charts: one-man surface-to-surface; multi-man surface-to-surface; and multi-man return-to-orbit vehicles. They include three one-man vehicles capable of 8, 20, and 170 km range; four two-man vehicles capable of 20, 50, 100, and 200 km range; four three-man vehicles capable of 50, 200, 400, and 800 km range; and a two-man and a three-man return-to-orbit vehicle.

In the flying vehicle conceptual designs, the approach was to make maximum use of data developed in past and current programs and to use common concepts for the various vehicles insofar as possible. Thus, the vehicles, particularly those for two and three-man crews, have many similarities such as the same landing gear and structural approach, the same type of propulsion systems using the same propellants, similar configurations in shape, same number and arrangement of propellant tanks, etc. For the initial designs during the conceptual design period certain assumptions were used. For example, thrusters were scaled to suit each vehicle and the multi-man vehicles were all assigned the same guidance system mass. When utilizing a flying vehicle for exploration, it will undoubtedly be used for multiple sorties and although the design point vehicles are capable of performing multiple sorties the vehicles were sized for a single flight of the range specified.

The accompanying illustration summarizes the one man pogo and multi-man return-to-orbit concepts. The F1B and F2B vehicles have been designated as primary DPVs for these groups. The remainder are secondary DPVs.

LFV CONCEPTS SUMMARY



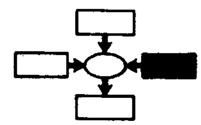
	POGOS			LOR	
	F1A	F1B	F1C	F2E	F3E
Fueled Mass (kg)	64	82	310	1106	1476
Range (km)	8	20	170	LOR	LOR
Crew Size	1	1	1	2	3
Development Cost ($M)	10.6	11.1	13.4	33.0	34.8
Development Time (Mos.)	24	24	24	42	42

MOBEV 3-65-1166

LFV CONCEPT SUMMARY—2

The accompanying illustration summarizes the multiman, surface-to-surface, lunar flying vehicle concepts. Within the group, F2E has been selected as a primary DPV. The remainder are secondary DPVs.

LFV CONCEPTS SUMMARY



Multiman Surface to Surface

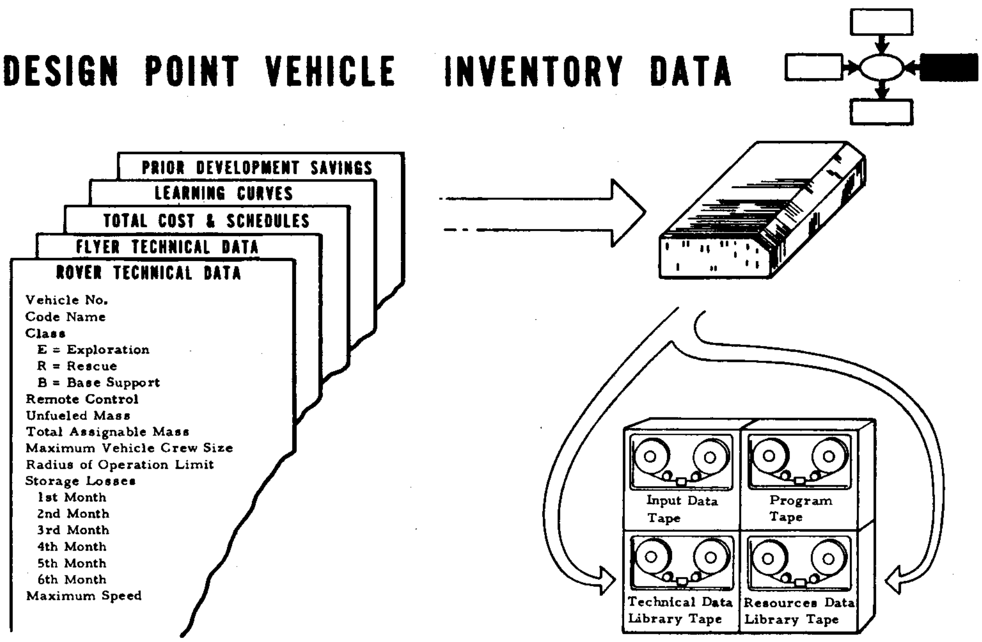
	F2A	F2B	F2C	F2D	F3A	F3B	F3C	F3D
Fueled Mass (kg)	288	392	530	788	529	1074	2066	4209
Range (km)	20	50	100	200	50	200	400	800
Crew Size	2	2	2	2	3	3	3	3
Development Cost ($M)	29.1	29.5	30.1	30.9	30.8	32.7	36.8	44.5
Development Time (Mos.)	42	42	42	42	42	42	42	42

MOBEV 3-65a -1166

DESIGN POINT VEHICLE INVENTORY DATA

In addition to assembly of the final, detailed design data book, technical and resources data concerning each vehicle were assembled for use in the methodology computer program. The technical data consist of such key items as: vehicle class and type, mass characteristics (unfueled and gross operating), maximum crew size, storage losses, speeds over various ELMS soil models, and expendables rates (life support and mobility). The resources data include total cost and schedules, learning curve effects, and prior development savings.

DESIGN POINT VEHICLE INVENTORY DATA



MOBEV 3-66-1166

MOBILITY TECHNICAL AND RESOURCES SUMMARY

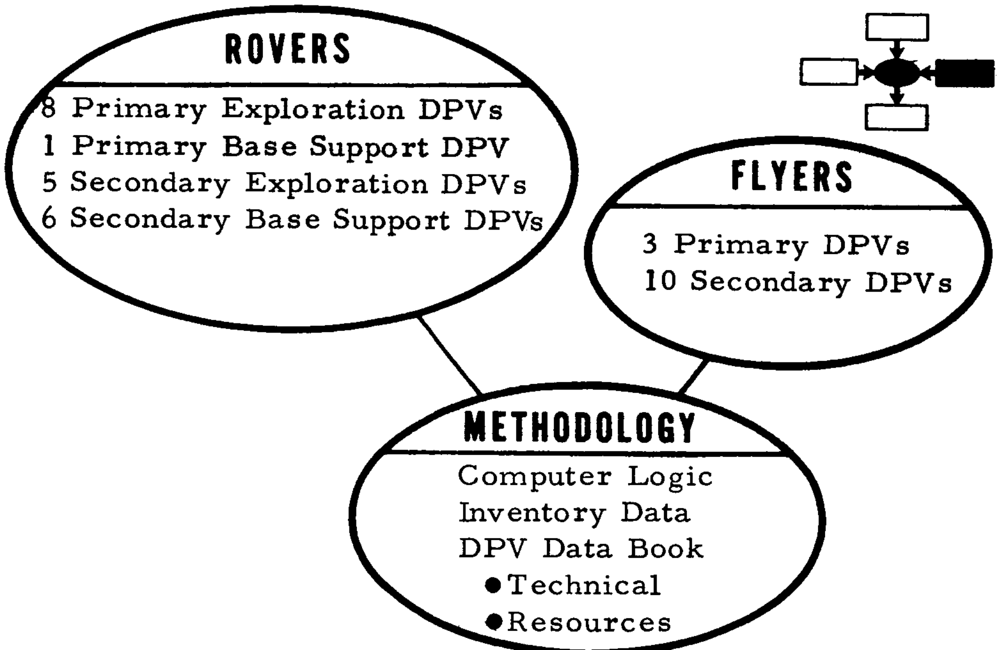
The data assembly and correlation effort has resulted in the conceptual design definition of roving and flying lunar surface mobility system design points sufficient to cover a wide spectrum of lunar exploration mission requirements. The Design Point Vehicles have been classified as either primary or secondary.

In general, the following definitions hold true:

1. Primary Design Point Vehicles—Design points throughout the mobility spectrum which represent unique and significant vehicles. These vehicles are significantly different in terms of crew accommodations, range and performance, technology advancement, operational lifetime, and scientific accommodations.

2. Secondary Design Point Vehicles—Design points throughout the mobility spectrum which represent intermediate or specialized functional capability. These vehicles offer weight and/or cost advantages for specific use and have been studied during the course of the program.

As a result of the study 20 roving and 13 flying DPVs have been defined. A Final Data Book which contains the details of the conceptual design of each vehicle as well as its resource requirements and comparative data on all vehicles have been prepared (BSR 1441). The particular design and sensitivity factors characteristic of each design were assembled for use in the evolution planning methodology.



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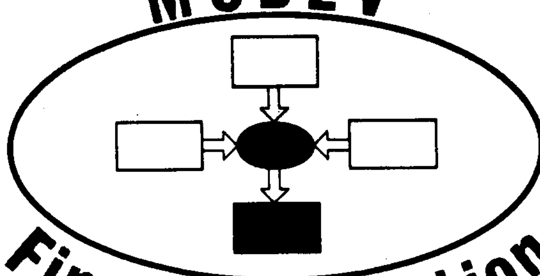
METHODOLOGY AND DECISION DATA

MOBEV



Final Presentation

MOBEV 3-68-1166

SPEAKER: HANK CORNILLE

DECISION DATA REQUIREMENTS

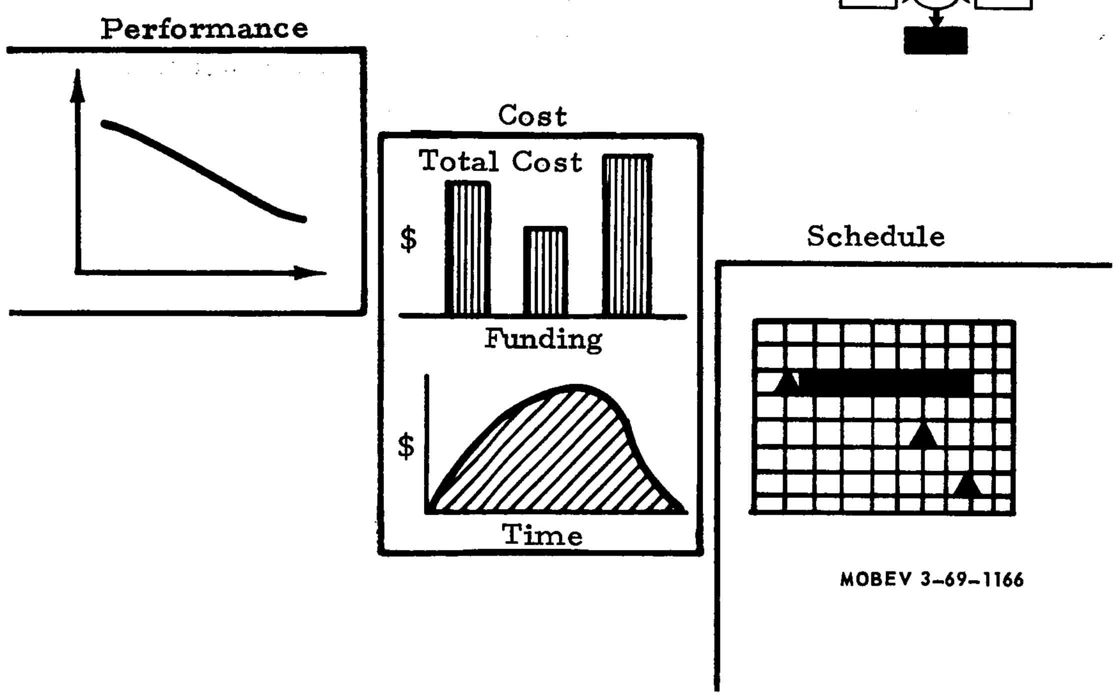
To select an evolution of lunar mobility systems, the planner requires data relative to vehicle performance, the total cost of vehicles and groups of vehicles which fulfill missions under consideration, funding requirements for individual vehicles and sets of vehicles, and, finally, schedule feasibility and required development start dates for the various vehicles with respect to the intended mission date.

Performance margin (the difference between vehicle performance capability and mission requirements) is useful to the planner to assess the contingency with respect to safety and also to determine if the other extreme is the case (the vehicle is very overdesigned for the mission under consideration). If a vehicle is rejected for a specified mission, the planner desires to know the performance deficiency so that recommendations may be made to the mission planners for variations in missions to achieve lower cost.

Total cost of an evolution of vehicles is of prime importance to the planner. However, of significant importance also is the expenditure rate or funds the planner must provide per fiscal period to carry out an evolution plan.

Finally, the planner needs to know when he should take action to commence the development of the vehicles in his planned evolution.

DECISION DATA REQUIREMENTS



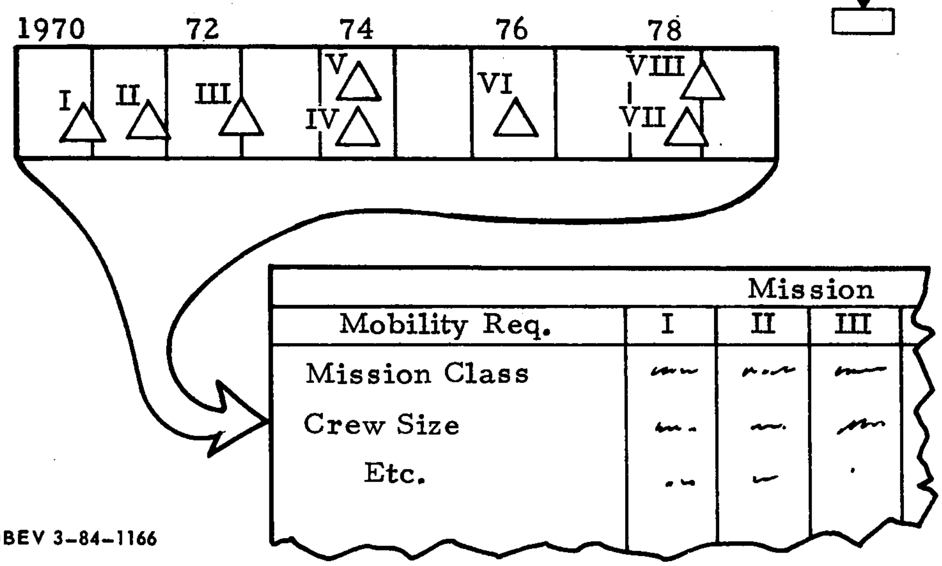
MOBEV 3-69-1166

TYPICAL PLANNER'S PROBLEM

A typical planner's problem consists of the selection of a mobility system evolution to perform a series of missions over a time period of interest. In the accompanying illustration, the diamonds with roman numerals represent the lunar missions requiring mobility support and their date of occurrence.

From these missions the planner derives the specific mobility requirements and constraints applicable to each of the missions. Examples of such mission parameters, and, subsequently, vehicle requirements, are mission total range, number of sorties, sortie ranges, payloads, crew size, mission or sortie duration, lunar storage time, etc.

TYPICAL PLANNER'S PROBLEM



MOBEV 3-84-1166

VEHICLE SELECTION AND SET FORMATION

Through the appropriate performance computations and checks of operational characteristics the planner can determine the suitability of each vehicle in the inventory for each mission to be considered along with the mass margins and other attendant performance data. He can also determine compatibility with constraints placed on each mission, such as total delivered mass.

The next task the planner must perform is the arrangement of acceptable vehicles in groups or sets (one for each mission) so that he may proceed with the development of resources data. This is necessary because the development cost and schedule of any vehicle is dependent upon preceding developments. The illustration shows how vehicles may be arranged according to the missions for which they are acceptable. The number of possible vehicle sets is given by the expression at the bottom of the illustration. For instance, if there are eight missions and two acceptable vehicles for each mission, the number of vehicle sets is 2^8 or 256. Obviously, many of these sets are illogical combinations and may be rejected by inspection. However, a substantial number will probably remain for which the planner will have to develop resources data before being able to select the most advantageous.

The total cost of a set must be determined by the cost of each vehicle, and summing. Vehicle costs may be comprised of non-recurring and recurring costs or just recurring costs. To find the proper cost for each vehicle, the planner must consider which other vehicles precede it in the set. Three situations therefore exist: (1) the vehicle being costed is the first vehicle in the set and therefore is not preceded by any other vehicles; (2) the vehicle being considered is a repeat article; (3) the vehicle under analysis is being used for the first time but is preceded by other vehicles in the set.

Costs for each vehicle in the inventory have been developed considering no prior developments. Further, prior development savings for major cost elements (e. g. , major subsystems, system integration, GSE) have been computed for every combination of vehicles, and learning curves to relate estimated repeat article savings have been established. Therefore, cost of vehicles in the first and second situation are readily obtained. For the first situation, recurring and non-recurring costs are applied directly. The cost of vehicles in the second situation (repeat articles) is also obtained fairly readily by subtracting non-recurring costs from the "no prior development cost" and applying appropriate learning curves to the recurring costs. In the third situation, the costs are determined by reducing the "no prior development cost" by the major cost element savings from prior development vehicles in the set.

VEHICLE SELECTION & SET FORMATION

	Mission					
	I	II	III	IV	V	VI
Accept-Able Vehicles	A	B	B	C	A	D
	B		D	D	B	E
	D		E			F

No. of Sets = $\text{No. V.}_{I} \times \text{No. V.}_{II} \times \ldots \times \text{No. V.}_{VIII}$

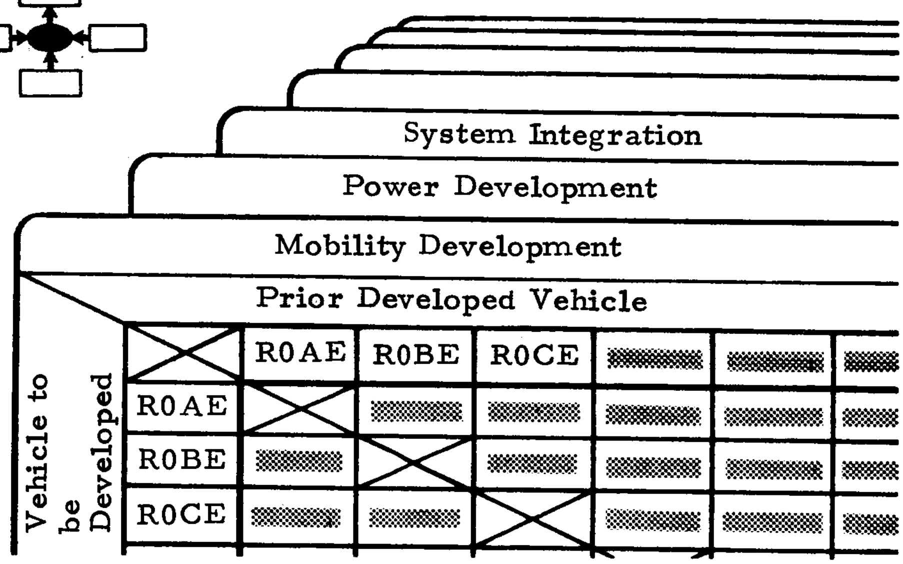
MOBEV 3-70-1166

COST COMPARISON MATRIXES

To determine the cost of vehicles in the third category (those that are not repeat articles but are preceded in the set by other vehicles), the planner must compare at a lower level. To facilitate this, a series of comparison matrixes have been developed. These matrixes allow the planner to compare any vehicle with any other vehicle in up to 15 major cost categories to determine the "cost savings" relative to the "no prior development cost" due to prior developments. Essentially these matrixes guide the planner in subtracting the non-recurring costs at a subsystem or major cost area level.

The specific subsystems or major cost areas vary somewhat with respect to flyers and rovers due to their different characteristics, i.e., mobility development and remote control OGE development apply only to rovers, while propulsion system development applies to flyers only.

COST COMPARISON MATRICES



MOBEV 3-75-1166

VEHICLE FUNDING DATA

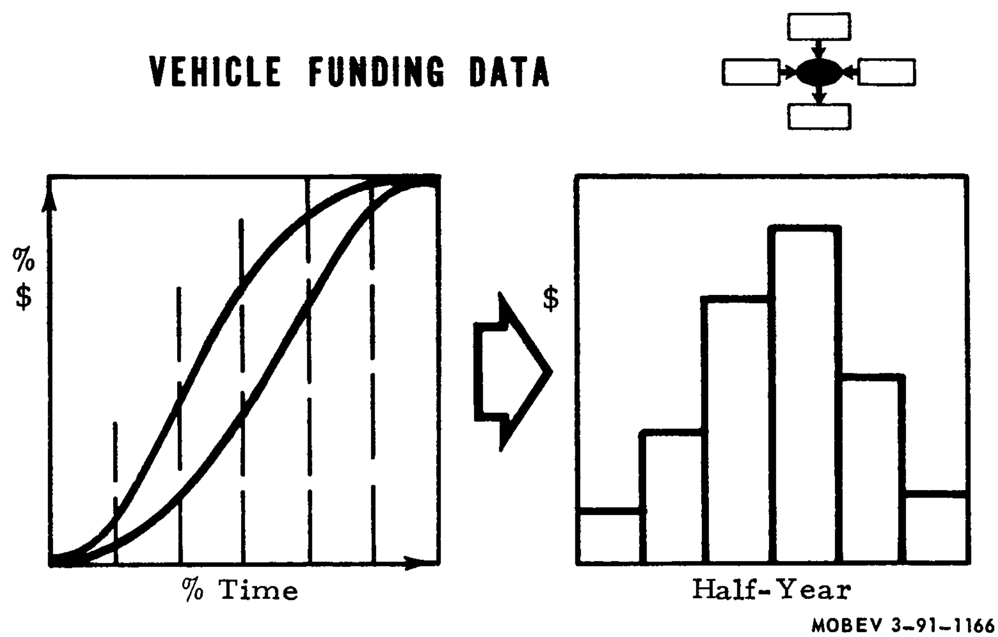
After obtaining the total cost of vehicle sets, the planner may desire funding data to either: (1) choose between two or more sets whose total costs are nearly equal; or (2) plan budgetary requests for the selected set.

The expenditure rate as a function of time, in reality, will probably vary as a function of vehicle type, size, and characteristics. However, no history exists to determine these exact relationships for a lunar mobility system. The approach taken was to generate a general relationship based on past studies which have gone furthest in resources planning.

Using the previously calculated development start date for each vehicle, the planner can apportion the total cost of each vehicle by time increments. Half-year increments were chosen for this purpose.

As the left-hand portion of the illustration shows, two relationships are utilized—one determining the committed funds equivalent to the planner's budgetary requirements, the other giving the actual funds expended by the system contractor.

VEHICLE FUNDING DATA

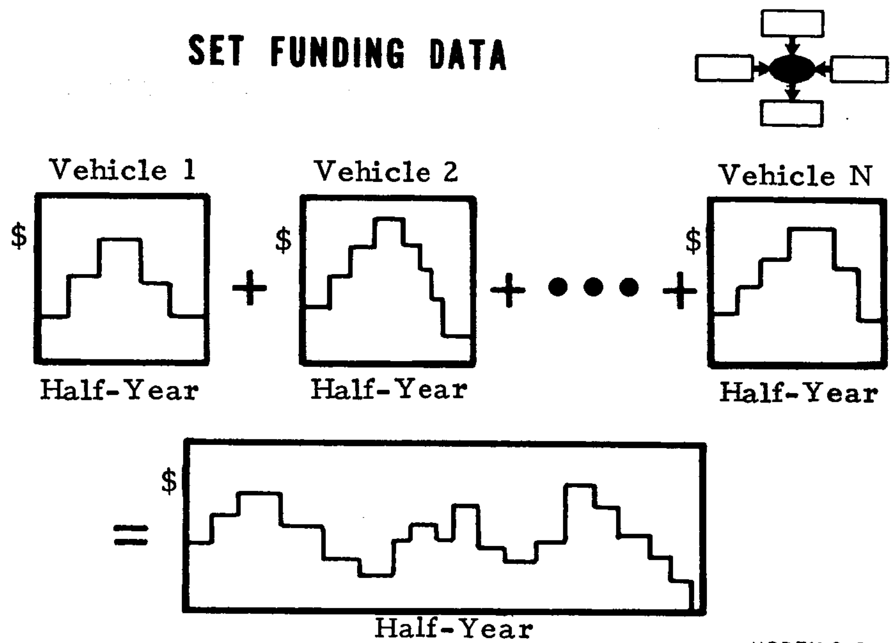


SET FUNDING DATA

The overall funding pattern for a set is obtained by summing the funds assigned to each half-year for each vehicle in the set.

While the funding calculations are not difficult per se, they are, however, very numerous, tedious, and time consuming, as is the determination of a vehicle cost using the cost comparison matrixes.

SET FUNDING DATA



MOBEV 3-76-1166

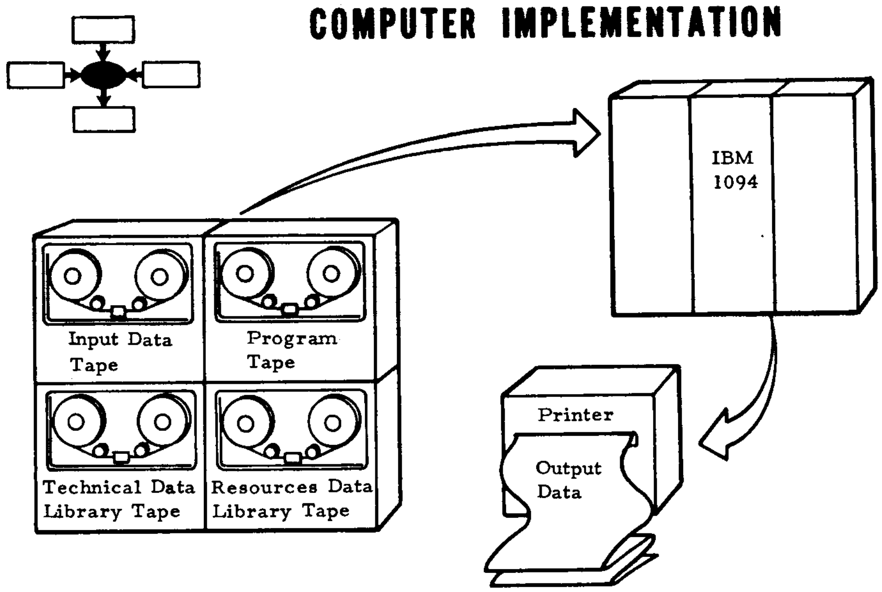
COMPUTER IMPLEMENTATION

The previously described operations have been programmed for computer implementation.

Four types are utilized for storage of data used in the program, while generating decision data for the planner. In addition to the program logic and the planner's input data, there are two library tapes. These tapes contain the infrequently changed Design Point Vehicle technical and resources data.

Program operations are performed on the IBM 7094 digital computer at the NASA Marshall Space Flight Center Computations Laboratory. Output data are presented to the planner as printouts from a standard printer.

COMPUTER IMPLEMENTATION



MOBEV 3-73-1166

PROGRAM CHARACTERISTICS

The gross characteristics of the computer program are presented in this illustration.

PROGRAM CHARACTERISTICS

- Problem Input: 5 - 75 Cards/Planner's Time < 4 Hrs.
- Program Language: Fortran IV
- Computer Run Time: < 30 Min.
- Missions Per Run: Up to 20
- Vehicles in Storage: Up to 50
- Funding Data: Up to 20 Sets/Run
- Complete Library Change: 4000 Cards

MOBEV 3-82-1166

PROGRAM ROUTINES AND SUBROUTINES

The computer program has been designed to perform the same operation that the planner normally would in the same general sequence except where greater machine efficiency could be obtained by alteration of the sequence of operations.

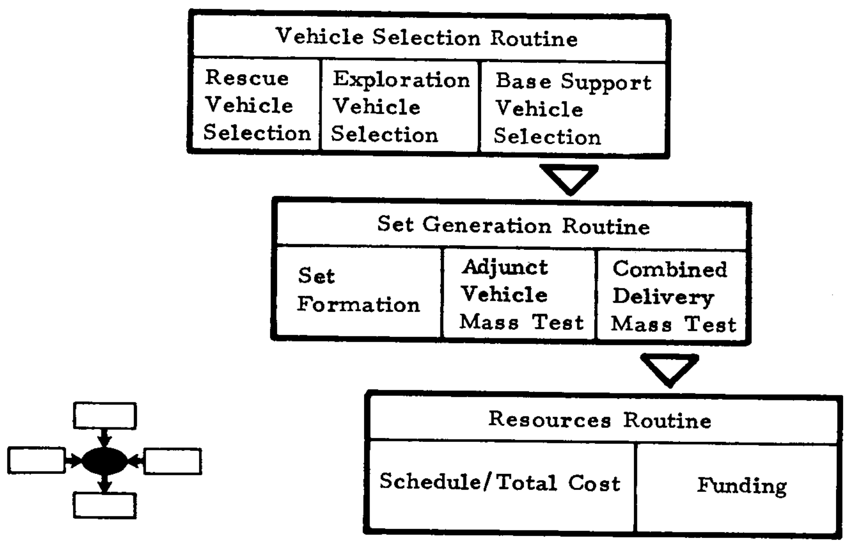
Three routines are contained within the program: (1) the Vehicle Selection routine, (2) Set Generation routine, and (3) Resources routine.

Within the Vehicle Selection routine, it has been found convenient to arrange subroutines according to the three fundamental mission classes: rescue, exploration, and base support.

Three subroutines are also contained within Set Generation. The first of these performs the function of forming the possible sets. The second and third, Adjunct Vehicle Mass Test and Combined Delivery Mass Test, apply tests which concern two or more vehicles within a set and therefore determine whether the set formed is valid or not.

The Resources routine is divided into two subroutines. Schedule/Total Cost performs the function of computing the total cost of individual vehicles and vehicle sets plus calculating the required development start dates for vehicles in the set. The Funding subroutine appropriates the committed and expended funds in half-year increments for the individual vehicles in the set and the total set.

PROGRAM ROUTINES & SUBROUTINES



MOBEV 3-85-1166

MISSION CLASSIFICATIONS

Although the vehicle selection has been based upon three specific mission classes, it has been necessary to divide these classifications further to reflect the applicable vehicle types and their characteristics and to allow for adjunct missions and combined delivery.

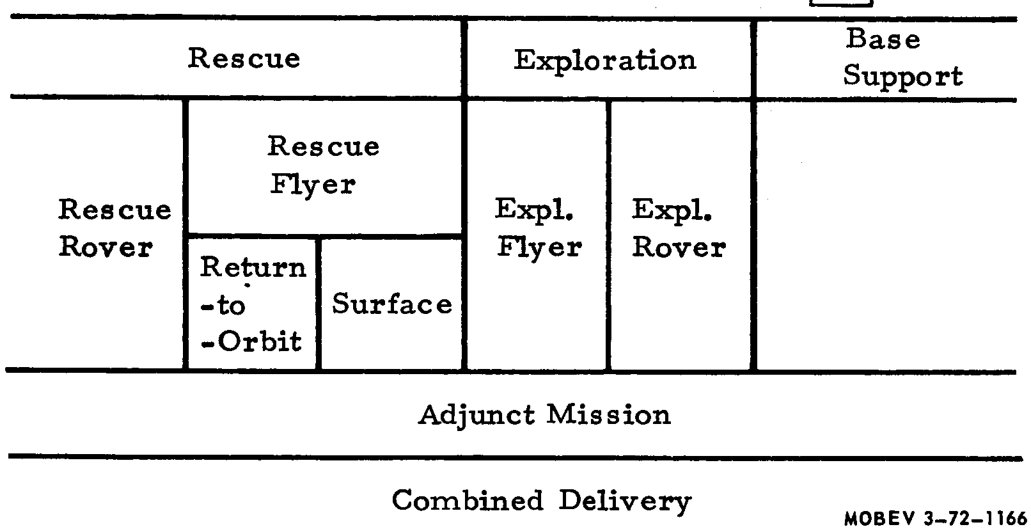
The adjunct mission is defined as one which commences at some distance from the landing point, the vehicle for the adjunct missions being transported to its point of mission commencement by another lunar mobility system termed the "parent vehicle."

The combined delivery refers to the lunar delivery of one or more mobility systems by a single delivery vehicle.

Based upon the anticipated requirements for base support missions, only rovers are considered suitable for these missions. Both flyers and rovers are applicable to rescue and exploration missions. Furthermore, rescue flyer missions must be considered to be either of the return to orbit type or surface rescue types.

As the illustration shows, the planner can designate an adjunct mission or combined delivery applicable to any of the other mission classes.

MISSION CLASSIFICATIONS



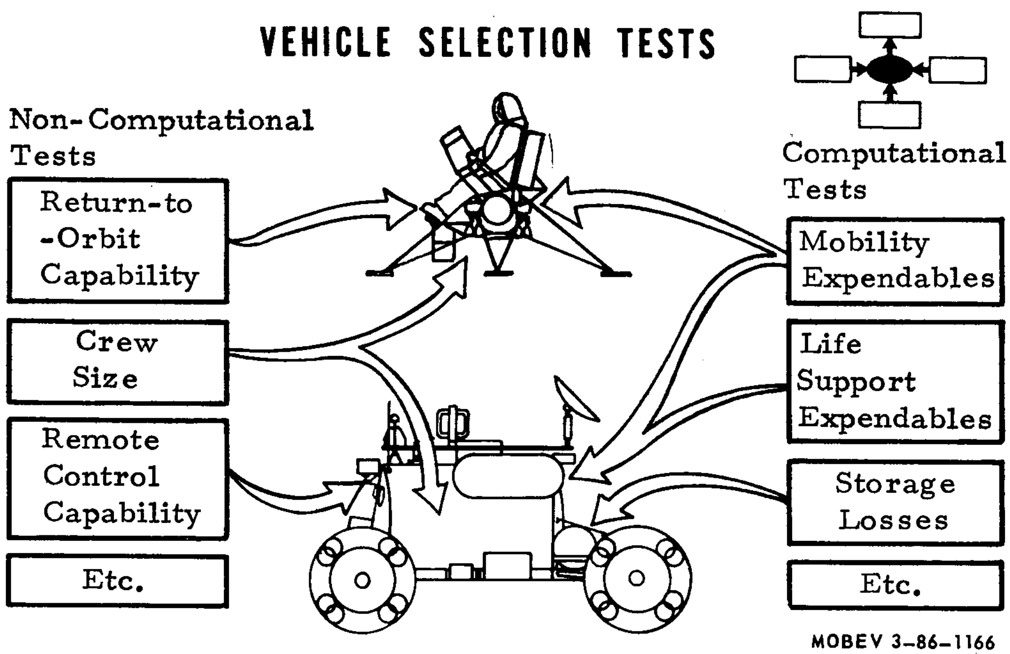
MOBEV 3-72-1166

VEHICLE SELECTION TESTS

The selection of a given vehicle for a specified mission is determined by the vehicle passing a series of programmed tests. The specific tests are a function of the mission class, vehicle type, and specific mission parameters. These tests are of two types: noncomputational and computational.

Noncomputational tests determine whether or not the vehicle under consideration possesses specific performance characteristics or equipment prerequisite to the specified mission.

The computational tests compute the mass of expendables required to fulfill the various mission functions. Each vehicle has an allowable total expendable mass. The value of this factor for rovers is the difference between the operational mass for which the mobility subsystem was designed and the fixed mass of the vehicle. For flyers, the maximum operational mass is determined by the thrust-to-weight ratio required for safe take-off.


VEHICLE SELECTION TESTS
Non-Computational
Tests
Return-to
-Orbit
Capability
Crew
Size
Remote
Control
Capability
Etc.
Computational
Tests
Mobility
Expendables
Life
Support
Expendables
Storage
Losses
Etc.
MOBEV 3-86-1166

MASS TEST OPTIONS

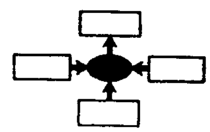
A variety of mass test options are available for specifications by the planner. He can specify a mass limit to be applied to the unfueled mass of the selected vehicle if he wishes to deliver the vehicle unfueled for use with a base or large shelter.

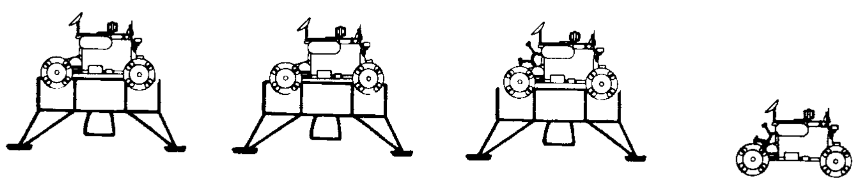
In applying the mass test for a vehicle to be delivered fueled, the program will compare the specified mass limit to the mass of a vehicle fueled with just sufficient expendables to fulfill the specified mission.

In using the combined delivery mass test, the mass compatibility of two more vehicles with a delivery system is assessed. The planner specifies the mass limit for which the vehicles are to be delivered by a common landing system and whether those vehicles are to be delivered fueled or unfueled.

The adjunct vehicle mass test allows the planner to input such missions as a rescue flyer to be carried on a rover. The test ascertains the mass compatibility of the two vehicles after they have been accepted as suitable for their specified individual missions. The combined delivery mass test can also be applied to these vehicles if they are to be delivered simultaneously.

MASS TEST OPTIONS





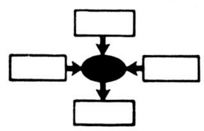
Unfueled   Fueled   Combined Delivery   Adjunct

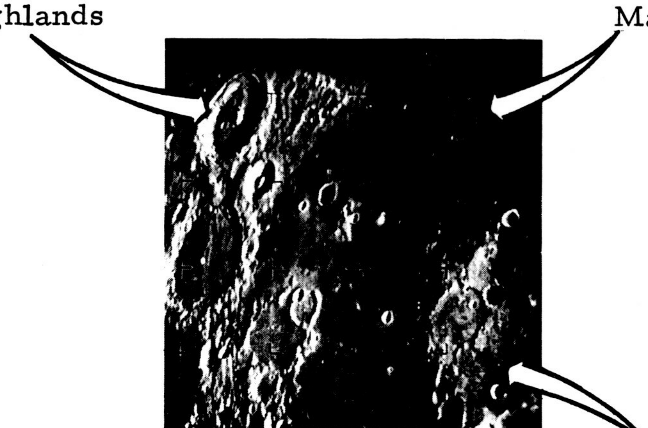
MOBEV 3–74–1166

SURFACE MODEL OPTIONS

In the stored technical data, space exists for rover performance data on four surface models. At present, performance data for three surface models are stored and the planner can specify which of these three he wants used for each mission. Addition of a fourth model or replacement of any of the presently stored three can be made by the planner at his discretion. The presently stored surface models are the ELMS Maria, ELMS Highlands, and model composed of 50% ELMS Maria and 50% ELMS Highlands termed "ELMS 50/50."

SURFACE MODEL OPTIONS





MOBEV 3-77-1166

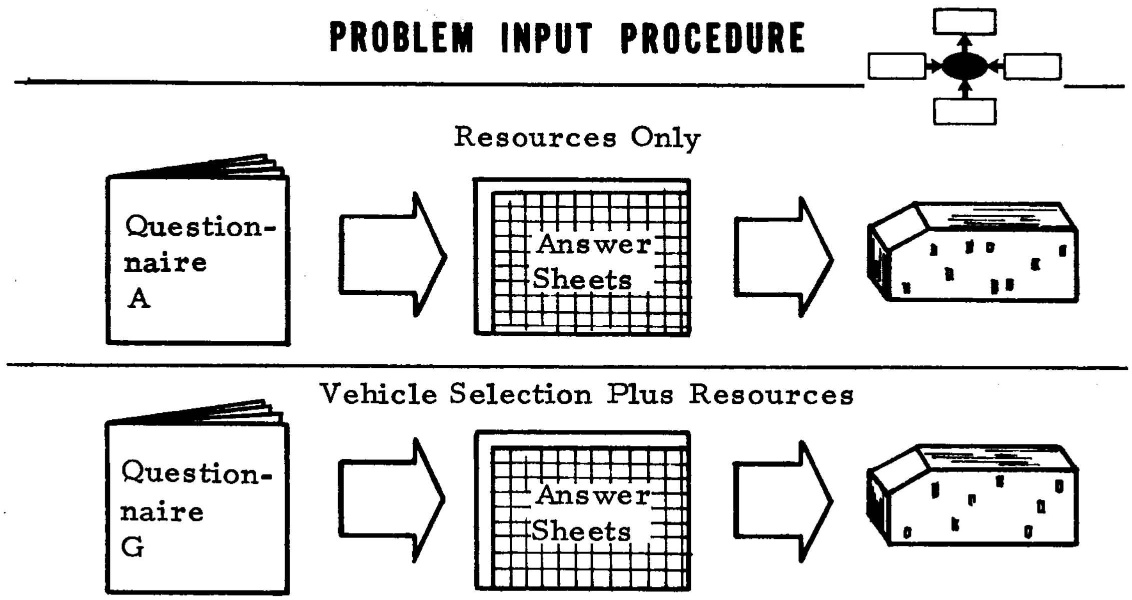
PROBLEM INPUT PROCEDURE

Two questionnaires are provided to assist the planner in inputing his problem. One applies when he desires to use the Resources routine only, the other applies for vehicle selection and resources.

Answer sheets are provided corresponding to each questionnaire. The planner enters the appropriate problem data in response to the questionnaire on these sheets and indicates the selected options.

The data are then punched on cards directly from the answer sheets and the problem is ready for execution.

PROBLEM INPUT PROCEDURE



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OUTPUT DATA OPTIONS

Five output data configurations are available at the option of the planner. Three of these apply when the planner is using the Vehicle Selection routine and the other two when only the Resources routine is utilized.

Output I consists of the acceptable vehicles for each mission, the utilization of expendables for each acceptable vehicle, and the first reason for rejection of unacceptable vehicles.

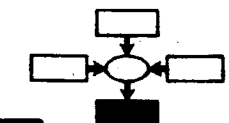
Output IV consists of the Output I data plus the required development start date for each acceptable vehicle and total cost of each vehicle in a set, and the total cost of a vehicle set.

Output V is comprised of the Output IV data plus funding by half-year increments for individual vehicles in a set and total sets. Both expended and committed funds are provided.

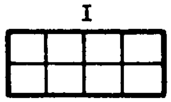
Output II gives total costs of vehicles in a set and set total cost. Optionally provided with this output is development start dates for vehicles in a set. The planner can either specify the development start dates for vehicles or let the program develop these data as an output.

Output III is the same as Output II except that funding data are also included.

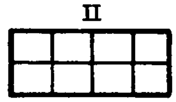
OUTPUT DATA OPTIONS



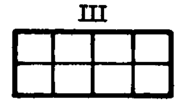
I



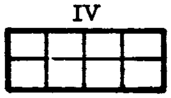
II



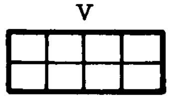
III



IV



V



Acceptable Vehicles	Expendables Utilization For Acceptable Vehicles	First Reason For Rejection of Unacceptable Vehicles	Vehicle Funding
Vehicle Development Start Date	Vehicle Total Cost	Set Total Cost	Set Funding

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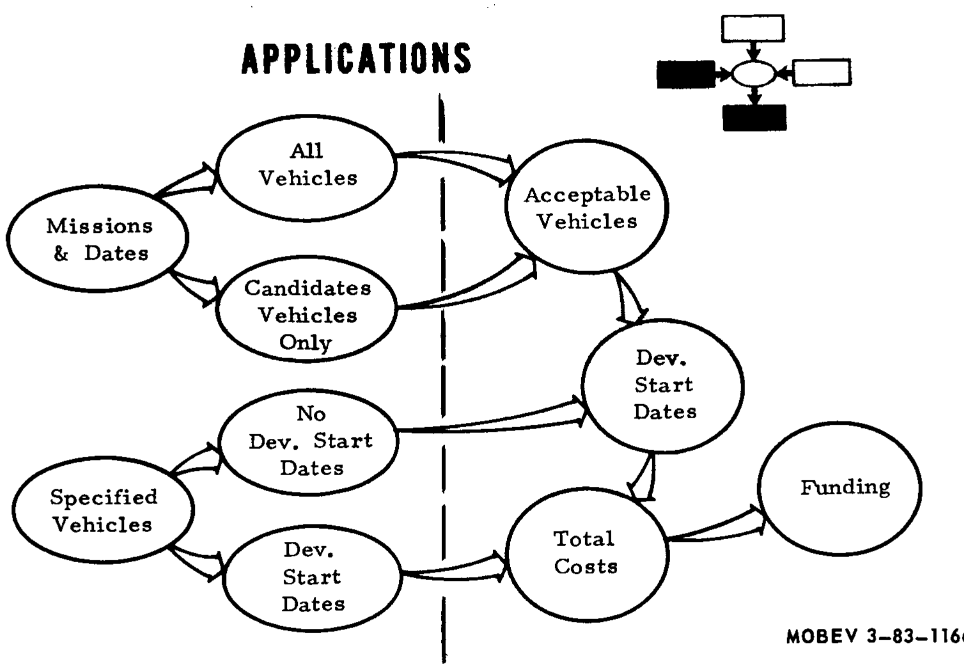
APPLICATIONS

There are two basic types of problems to which the planner can apply the methodology: (1) problems in which missions are specified, and (2) problems in which vehicles but not missions are specified.

If vehicles are to be selected for missions the planner can allow the program to select from the entire inventory of vehicles or only designated "candidate" vehicles. In either case, he also has the option of specifying Output I, IV, or V.

When using only the Resources routine the planner may specify development start-date or let the program generate these data, and may specify either Output II or Output III.

APPLICATIONS



SPECIAL APPLICATIONS

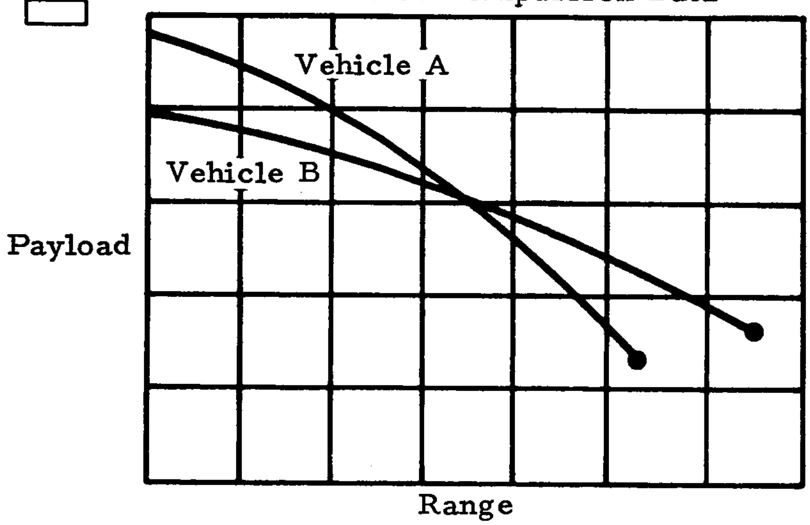
Many special applications of the program exist. One would be the development of parametric mission performance data for specific vehicles.

The particular case illustrated here is range versus payload data. These data can be generated for various crew sizes, etc.

The specific data of interest are obtained by inputing missions of various ranges with no payloads. The resultant mass margin at each input range then represents the allowable payload at that range. The vehicles of interest are, of course, designated as "candidate vehicles."

SPECIAL APPLICATIONS

Performance Comparison Data



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SPECIAL APPLICATIONS

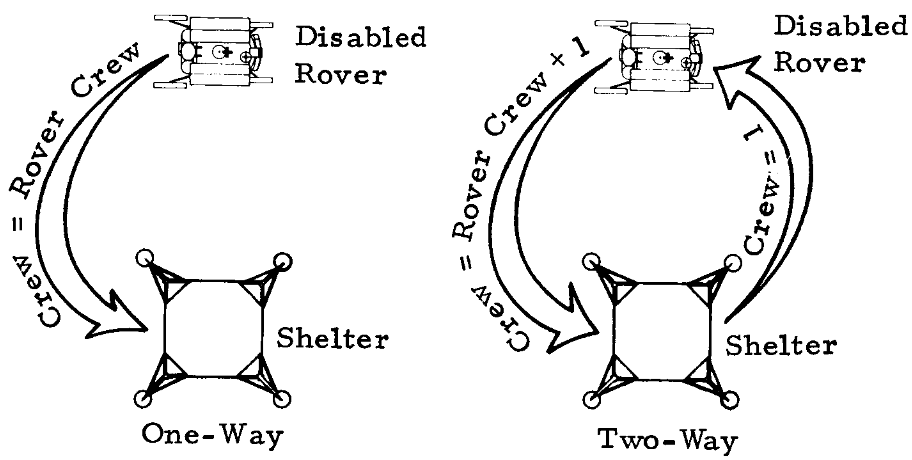
Another special application of the program is its use in configuring missions.

A particular example of this is the one-way versus two-way rescue, as illustrated. In the one-way rescue, the rescue vehicle is to be carried as an adjunct. In the two-way rescue, the rescue vehicle is retained at the shelter or base until needed. The one-way mission requires a lower mass rescue vehicle, but may necessitate a large exploration vehicle mass since the rescue vehicle must be carried on the exploration traverse.

The total mass delivered to the lunar surface, the rescue time, and other data can be obtained by the planner for these configurations as a function of rescue range, crew size, etc.

SPECIAL APPLICATIONS

One-Way vs. Two-Way Rescue



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MOBEV SUMMARY

The MOBEV Program has the basic objective of providing the NASA Planner with a methodology to select a vehicle evolution which covers a broad mission spectrum for the 1970 to 1980 time period. The MOBEV Program provides this tool to give the planner both resources and technical data on each of the vehicles.

The methodology has been computerized and NASA has been provided with computer logic and design data books. Thirty-three Design Point Vehicles based on an anticipated mission spectrum definition are included in the design data books and computer data bank. Data are also included for rubberization of each of the vehicle concepts by expendables trade-offs and subsystem scaling.

In summary, the Planner's methodology provides the following:

1. Selection, performance, and resources data for DPVs (computerized)

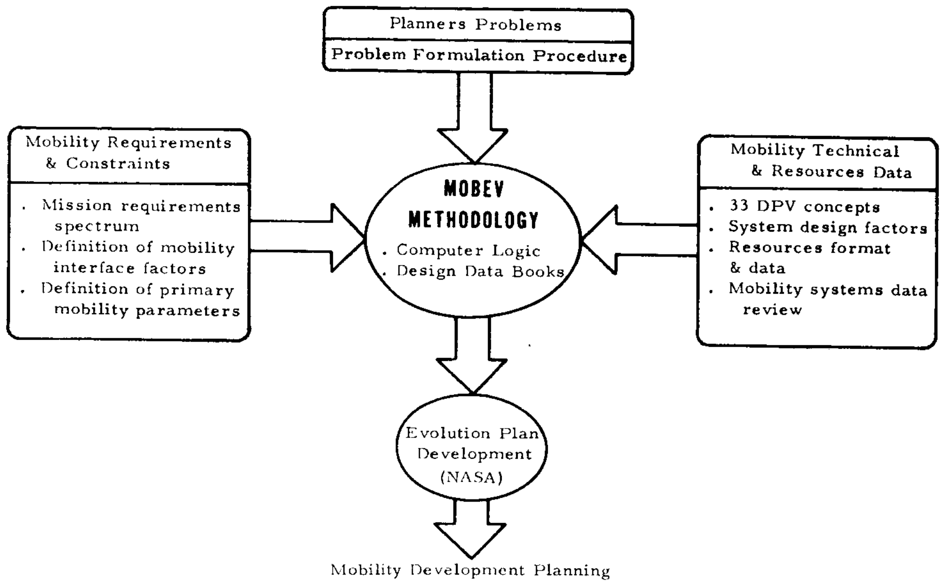
2. Partial rubberization of DPVs by expendable trade-offs (computerized)

3. DPV detailed technical and resources data (Design Data Book)

4. Vehicle set generation and resources data (computerized)

5. Evaluation of DPV sets and vehicles in set (computerized)

6. Mission assessments and recommendations for mobility requirements (computerized including reject analysis).



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