[redacted]

RE-ORDER NO. 64 127

SURVEYOR
LUNAR ROVING VEHICLE,
PHASE I

BSR-903

FINAL TECHNICAL REPORT

SUBMITTED TO

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY

JPL CONTRACT
950656
under NAS 7-100

VOLUME I
PROGRAM SUMMARY

APRIL 1964

Bendix SYSTEMS DIVISION

[redacted]

[redacted]

LIST OF VOLUMES

➡ VOLUME I – PROGRAM SUMMARY

VOLUME II – MISSION AND SYSTEM STUDIES

VOLUME III – PRELIMINARY DESIGN AND SYSTEM DESCRIPTION
  Book 1 – System Description and Performance Characteristics
  Book 2 – Validation of Preliminary Design

VOLUME IV – RELIABILITY

VOLUME V – SYSTEM EVALUATION

THE DOCUMENT YOU ARE READING IS INDICATED BY THE ARROW

[redacted]

TABLE OF CONTENTS

SECTION 1

INTRODUCTION

This volume of the Final Technical Report summarizes The Bendix Corporation's efforts during the SLRV Phase I study program conducted under JPL Contract No. 950656, Modification No. 1.

The contract statement of work required Bendix to conduct "a design study and engineering test model development program for a roving vehicle payload for the Surveyor lunar soft landing spacecraft. The primary purpose of the roving vehicle payload is to provide a capability for making surveys to obtain basic data in support of the manned lunar landing program and to contribute new scientific knowledge about the moon".

This volume contains the over-all program conclusions and recommendations and a summary of the mission and system studies that led to these conclusions. A description of the preliminary design of the 100-lb system is given, and the areas of design emphasis for Phase II are indicated.

The other volumes of the Final Technical Report contain all the significant trade-off studies and resulting design details necessary to establish the feasibility of the 100-lb SLRV concept and to determine the performance and reliability increases that would result from vehicles weighing more than 100 lb.

SECTION 2

SUMMARY OF PROGRAM CONCLUSIONS

The objectives of the Phase I SLRV study program were threefold: (1) to define the specific SLRV missions and the factors influencing their selection within the constraints expressed in EPD-98, Revision 1, and other applicable documents; (2) to determine the extent to which it is feasible to implement these missions within a 100-lb gross weight limit; and (3) to analyze the potential gains in performance and reliability for systems with gross weights in excess of 100 lb.

Toward these objectives, execution of the Phase I study effort has resulted in the conclusions which are summarized below and discussed in more detail in subsequent sections.

2.1 MISSION ANALYSIS

The major conclusions from the mission analysis effort are as follows:

1. The primary mission for SLRV should be defined to relate directly to a significant increase in the probability of a successful LEM landing.
2. The increase in probability of successful LEM landing is achieved by SLRV's ability to locate and certify acceptable landing sites. This increment of success probability should be achieved with a 99% confidence.
3. The SLRV approach can be at least four times as effective for the Apollo landing site verification mission as any other existing or planned program.
4. To maximize the probability that SLRV will accomplish this mission, the SLRV should be required to collect only that data needed for site identification and certification.

[redacted]

5. Besides determining that a point is acceptable or unacceptable for LEM landing, the SLRV must also provide data with which the LEM astronauts can locate the acceptable landing points.

6. Development of the SLRV is warranted if the probability that a single vehicle will accomplish the primary mission is greater than 0.13. A probability of 0.5 is recommended as a goal.

7. Assuming a satisfactory confidence in the probability of a successful Surveyor landing, all other elements of the SLRV concept are completely feasible.

2.2 SYSTEM ANALYSIS

The SLRV system analysis studies resulted in the following significant conclusions:

1. The survey of a limited portion of the lunar surface, in a carefully selected pattern of discrete LEM landing points, has been established as the preferred mode of operation.

2. The system must be capable of performing accurate navigation.

3. To complete a mission which satisfies the requirements established above, the SLRV must provide a capability for near real-time judgment of the surveyed area's acceptability.

4. A direct-link communication system between the SLRV and the Deep Space Instrumentation Facility (DSIF) ground station is required.

5. For the above-defined mission, the SLRV concept is feasible within the 100-lb limitation. The confidence level associated with this feasibility can be improved significantly if the system's gross weight allocation is increased to approximately 125 lb.

6. The 100-lb system must operate for a period of not less than 3 months. For equivalent surface conditions, a 125-lb system would be required to operate for no less than 2 months.

[redacted]

2.3 SYSTEM DESIGN

The system design effort has resulted in the following major conclusions:

1. The SLRV system will require a highly effective remote control technique. The study effort resulted in several feasible techniques for remote control and emphasized the significance and subtlety of the problems involved.

2. To maximize the confidence in the success of the SLRV mission, the SLRV design must have the maximum degree of intrinsic safety (for example, it must include high stability and warning features).

3. Because of the sensitivity of the SLRV performance (mobility, maneuverability, and mission time) to the lunar surface conditions, equipment flexibility should be a design requirement. Particularly, the mobility, instrumentation, and communication subsystems should allow for modification as the flight program progresses.

4. A high-gain directional antenna is required on the SLRV to provide sufficiently high data rates for video information, thus ensuring that mission time does not exceed the established value.

5. A radioisotope thermoelectric generator (RTG) power supply is a firm requirement.

2.4 DETAIL DESIGN

The preliminary design effort has resulted in the following significant conclusions:

1. A vehicle design adequately balanced among mobility, power, telecommunication, and instrumentation subsystems has been achieved inside the 100-lb limitation. A full-scale ETM has substantiated mobility predictions.

[redacted]

2. No major state-of-the-art advance is required for detail design and implementation of the SLRV system concept.

3. Certain basic data must be acquired during Phase II, primarily in the areas of materials, thermal coatings, and lunar soil behavior These needs are not considered limitations to feasibility, but are simply areas where more data are required to ensure a high degree of confidence. It is not anticipated that any advancement in techniques will be required. A 5-lb increase in weight allocation for reliability is desirable.

[redacted]

SECTION 3

MISSION ANALYSIS

The probability of a successful Apollo LEM landing is directly proportional to the percentage of acceptable area within the site if no prior verification is made, plus a small increase resulting from the LEM crew's capability for identifying and avoiding obviously hazardous areas. However, by location and identification of specific acceptable landing points in a carefully-selected pattern compatible with the LEM translational capability, the probability of a successful landing can be significantly increased—even when only a small portion of the total area in the site is acceptable. Therefore, the criterion for evaluation of the SLRV mission is the degree of LEM successful landing probability and the confidence provided, rather than the absolute capability to provide verification of the acceptability of some percent of the area within the site with a given confidence.

For the SLRV program to be at least four times as effective for the Apollo landing site verification mission as any other existing or planned program, it must have a single-launch probability of success greater than 0. 13 (based on a total of eight launches). The four-to-one effectiveness ratio is considered a prerequisite to development of the program. However, if an 0. 99 probability of establishing one acceptable LEM landing site is desired, the corresponding single-launch probability of success would be 0. 5. This latter value is established as the system goal.

Commensurate with a defined mission of verifying specific LEM landing points, the SLRV system must provide means for site identification and navigation to an acceptable landing point by the LEM crew; otherwise, a negligible increase in the confidence of a successful LEM landing is obtained.

Instrumentation and other data collection capabilities extraneous to the primary mission objective should be excluded from the system to maximize the probability of successfully accomplishing the primary objective.

In the analysis to establish the single-launch probability of success required for a feasible mission, it was determined that the probability partial having the lowest confidence is that pertaining to the Surveyor landing.

SECTION 4

SYSTEM ANALYSIS

The primary factors that affect all SLRV system trade-offs are reliability, weight, and power. For system design, it is useful to establish a feasible power-to-weight ratio for the power supply subsystem and then conduct all system trade-offs in terms of composite weight; i. e., subsystem weight plus equivalent power supply weight. Complexity and total operating time are the dominating parameters in the reliability predictions. Thus, the critical factors used in system design are composite weight, system complexity, and mission time.

Functions that affect the mission time are vehicle speed, total mission range requirements, data transmission rate, and operator decision time. All system elements affect and are affected by the composite weight. Mission time is essentially unrelated to vehicle speed in the range of practical speeds for the 100-lb weight constraint. Therefore, total vehicle range, the operator's decision time, and the communication data rate are the most significant contributors to the total mission time.

A primary SLRV mission operation has been developed; i. e., a sequence of 19 discrete LEM landing point surveys. This definition allows the total vehicle range requirement to be predicted with reasonable accuracy. Therefore, the effect of the total range requirement on mission time does not change appreciably when other system functions are varied. Thus, the second factor, operator's decision time, is more significant in determining total mission time and has a direct bearing on system reliability.

Operator decision time required for executing commands can be determined with reasonable accuracy. The major variable in decision time is the allowance for determining whether the surveyed area is acceptable or unacceptable. If this decision depends on the interpretation of a 25-cm contour map (produced from data supplied by the SLRV), then a fundamental strategy decision must be made. The time required to process the raw video and telemetry data into a contour map (for one pair of images) can be as much as four hours. Many pairs are needed to cover a single LEM landing point. It may therefore be decided either to wait until the map is produced at each stop of the vehicle within the landing point or to direct the vehicle to complete the data-gathering mission and proceed to another potential landing point with verification of the landing point just examined being established much later. The first alternative -- waiting for the map before the vehicle proceeds -- is obviously impractical since the nominal point survey time for data collection would increase from approximately 8 hours to as much as 300 hours.

On the other hand, if data are gathered at one landing point and the vehicle is then directed at once to the next point, it is highly probably (because in a reasonable lunar surface model approximately 50% of the landing points surveyed may be unacceptable) that the vehicle will have to be redirected from the unacceptable point to search for an acceptable one. This approach also would increase the mission time in two ways: (1) an additional eight hours would be required to survey a new landing point; and (2) additional time would be required to move to the new point and reduce the resulting new data.

These studies indicate that the feasibility of the SLRV concept requires the development of high-confidence techniques for determining the acceptability of a landing point in real time (minutes rather than hours) as the survey progresses. Several such techniques have been investigated and tentative solutions are discussed in Volume II. Although more work is required, this development effort does not constrain the over-all feasibility of the basic SLRV concept.

The third factor that contributes to mission-time, and thus to reliability, is the data-rate capability for both video and status telemetry information from the SLRV to the ground station. Two approaches exist. The Surveyor spacecraft could be used as an active relay link between the SLRV and DSIF. But examination of the lunar surface models specified in EPD-98 and a survey of similar types of terrain (such as exist in the Bonito Lava Flow) indicate that the ability to maintain line-of-sight contact beyond several hundred feet from the Surveyor spacecraft is extremely doubtful; and in a relay system, the loss of line-of-sight contact means the loss of communications.

Consequently, the required high data rate must be achieved by optimizing a direct communications link between the SLRV and DSIF. The resulting choice between a high-gain antenna and a high-power transmitter is a system design decision.

To satisfy the primary mission objective of site verification within the capabilities of a 100-lb system, the mission must consist of the certification and identification of a number of discrete landing points which are at least 40 meters in diameter and spaced no more than 528 meters apart. In terms of vehicle capability, this is several orders of magnitude less severe than complete survey of the 3200-meter area. There is an associated penalty, however, in terms of SLRV navigation accuracy requirements for locating the landing points and the reference marks to be used in navigating LEM to the acceptable points. The penalty in terms of SLRV mission range, and thus mission time and reliability, increases approximately in proportion to the square of the errors in the navigation system. However, by using state-of-the-art techniques, navigation systems with sufficient accuracy can be developed so that the percent increase in mission range attributable to navigation errors will be negligible.

From the results of the system analysis and the subsequent evaluation of the preliminary design given in Volume V, it is concluded that the postulated primary mission can be accomplished by a 100-lb vehicle with a satisfactory probability of success, including mechanical reliability; but confidence in the system's ability to achieve this level of performance is undesirably low. If gross system weight is increased to approximately 125 lb, the confidence level associated with system feasibility can be improved significantly.

System analysis has defined maximum anticipated mission time as from 3 to 3-1/2 months for the 100-lb SLRV and from 2 to 2-1/2 months for the 125-lb SLRV; depending on lunar surface conditions.

A computer evaluation program was developed to analyze the performance characteristics and probability of success of the 100-lb SLRV concept. Results showed that the vehicle performance optimization (particularly mobility, maneuverability, and mission time) is highly dependent on the lunar surface model used in the evaluation. This dependence indicates the need for a high degree of retained design flexibility so that the SLRV can be quickly modified if data from other lunar programs and early SLRV operations show that modifications are needed.

[redacted]

SECTION 5

PRELIMINARY DESIGN

5.1 SYSTEM DESIGN

The major trade-offs in the system design involved optimizing power data rate, and vehicle speed to achieve the shortest mission time. The most sensitive of these trade-offs was the difference between high-gain directional antennas and omni-directional antennas. Weight trade-off studies for these two approaches show that the difference in mission time, and the resulting effect on reliability, is directly proportional to the data rates of the two antenna configurations. On this basis, a directional antenna was established as a firm requirement for SLRV feasibility.

Other primary trade-offs arrived at in achieving system design were concerned mainly with the trade-off of mobility subsystem weight vs. weight allocated for reliability in terms of redundancy and improvement in the basic subsystem design. However, the computer evaluation program indicated that the result of this trade-off is highly sensitive to the choice of lunar surface model. Therefore, only qualified conclusions could be made, which are discussed in Volume V.

A third major conclusion in system design dealt with vehicle control and safety. It is not advisable to rely entirely on operator display and controls for safety because of the possibility of losing contact with the vehicle. The unknown nature of the lunar surface and the inherent transmission time delay between the moon and the earth make it essential that the vehicle design have intrinsic safety features to the maximum practical extent, including the use of such sensors as the inclinometer. One measure of inherent design safety is the static and dynamic stability limits of the vehicle as related to the vehicle's ability to place itself in a condition of marginal stability. Other inherent safety features include the ability to operate with equal capability in both the fore and aft directions and the avoidance of protuberances, low undercarriage clearance, etc., which might immobilize the vehicle.

[redacted]

In addition to the inherent safety features of the vehicle, studies of ground operator display and control problems have shown that it is feasible to accomplish the primary mission with the 100-lb system containing a monoptic image-sensor mechanism. However, the ability to control the vehicle would be improved appreciably by the inclusion of a fixed-based stereo imaging sensor on the vehicle: this would require approximately 7 lb additional weight.

One of the early system design conclusions (after the approximate mission times were established) was that a radioisotope power supply (RTG) is required. Studies indicated that for daytime operation only, without nighttime survival, a solar-array power supply would be most practical. However, with the advent of the requirement to survive as many as three lunar nights, the addition to the solar array of batteries or auxiliary RTGs resulted in an excessive subsystem weight. The only practical system (based on 3-month operation in the 1967 time period) is an RTG with a power-to-weight ratio of 1.85 watt/lb. Discussions with both JPL and the Atomic Energy Commission have confirmed the basic feasibility of developing such an RTG.

5.2 SYSTEM DESCRIPTION

The SLRV system consists of a vehicle, certain modifications to the Surveyor spacecraft, associated ground operating equipment, and the necessary ground support equipment. The system operates in conjunction with the Surveyor spacecraft, DSIF, the Space Flight Operations Facility (SFOF), and the Centaur launch vehicle.

The ground operating equipment at DSIF/SFOF provides operational control of the vehicle in locating and surveying potential landing sites and analysis and display of the data.

The SLRV developed during the preliminary design study is shown in the Frontispiece and Figure 5-1. It is a four-tracked articulated design with two main body sections. The aft section carries the RTG, the directional antenna, and the odometer. The forward section contains the electronic equipment, the bearing-strength penetrometer, the omni-directional antenna, the RF ranging antenna, the television camera, and four solar aspect sensors.

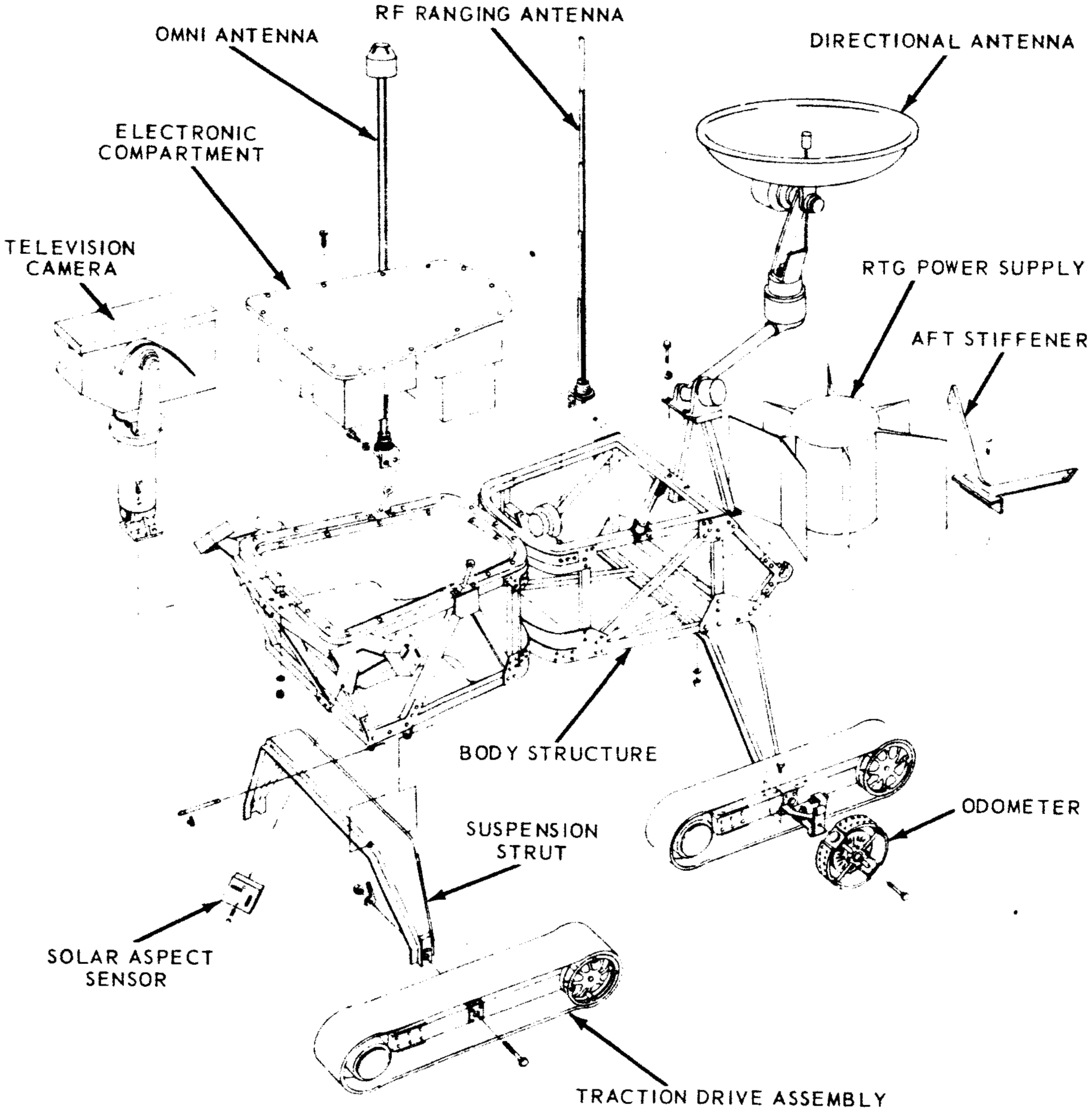

Figure 5-1 SLRV Configuration

In the stowed configuration, the SLRV is hinged to the Surveyor structure and held by spring-loaded, squib-actuated deployment latches. Deployment commands are received by the SLRV through an umbilical located near the deployment springs. The SLRV can operate independently of the Surveyor spacecraft after deployment; it will communicate directly with the ground complex.

The vehicle is steered by differential control of the speed of the four independently powered tracks, allowing the articulated structure to pivot near the center of gravity. The SLRV thermal control subsystem is mainly passive (the TV camera is semi-active) and primary power is supplied by the RTG. The SLRV is designed to survive in the lunar night environment.

Telemetry data can be transmitted continuously to the earth. Scientific information is obtained with the TV system, penetrometer, inclinometer, and odometer. Navigation is based on a dead-reckoning technique supplemented by RF ranging when the Surveyor is in the line-of-sight. The mission is performed in an intermittent manner by commanding the SLRV to proceed in steps of about three meters; commands are based on TV information obtained while the SLRV is stopped. Steering is controlled from the ground station by an operator-directed, computer-implemented procedure.

The vehicle has a ground clearance of 27 cm under lunar gravity loading conditions. The stability of the vehicle and the mobility design features provide a capability of traversing a wide range of anticipated lunar surface conditions (e.g., 40-cm steps, 29-cm crevices, slopes up to 25°, and 1 psi/ft bearing strength). The preferred mission operation covers a circular area 3200 meters in diameter from the point of its deployment, but the pattern can be varied at will.

The SLRV instrumentation provides data on lunar topography and surface bearing strength. For bearing strength, penetrometer data are supplemented by TV observation of track sinkage and slippage. The probe tube of the penetrometer mechanism contains a sensing element in the tip to measure force vs sinkage. The tube is a unique unfurlable design that extends to a maximum depth of 50 cm below the surface. At a depth of 50 cm below the surface, a signal is generated that automatically reverses the motor and withdraws the probe. A safety factor is provided in the form of a predetermined load setting within the mechanism to guard against failure of the probe tube or tipping of the vehicle if the probe impinges on a rock or other hard material.

The SLRV television equipment provides pictures for (1) the earth-based operator to steer the vehicle, (2) photogrammetry, mapping, or charting, and (3) selecting promising areas for survey. In addition, the TV provides for close-range monitoring of the surface before or after penetrometer experiments to correlate with bearing strength data. The TV field of view is controllable (10°, 22.5° and 50°), thus providing for reasonable side vision in a wide-angle position and long-range detection of small obstacles or crevices in the narrow angle position. The 10° setting is used for triangulation and for making charts of the lunar site. The TV resolution permits proper control of the vehicle and experimental coverage. The format is square with equal horizontal and vertical resolution (512 picture elements). An elevation movement from +15° to -60° is provided to permit a close view of the tracks and experiments at ground level and to permit views of the horizon when the vehicle is tipped downward at 15°.

The command receiver accepts commands from the earth via the S-band link through an SLRV omni-directional antenna and uses FSK modulation for compatibility with the present Surveyor command system.

The data-handling equipment processes received messages, provides execution signals to various subsystems, and multiplexes inputs from telemetry sensors and the TV subsystem for transmission to earth. The command processor can decode discrete and proportional commands generated by the DSIF command and data-handling consoles. Redundant command decoder units are included. The processor also provides address and magnitude signals for controlling the television subsystem, the mobility of the vehicle, scientific experiments, and general engineering functions.

The communication link for video data uses a two-watt transmitter with a 17-db directional antenna attached to the top of the SLRV. The omnidirectional antenna is used for telemetry transmission. The design is based on a 10^{-3} error rate capability, an 8-db performance margin, and the use of the 210-ft antenna at the Goldstone station. Telemetry, but not video, can be received with an 85-ft DSIF antenna.

The navigation subsystem will locate the SLRV in lunar surface coordinates relative to the Surveyor spacecraft or other references. Data on surface distance traveled, instantaneous heading, and instantaneous slope are also used in determining the surface contour. The SLRV heading on the lunar surface is obtained from solar aspect sensors in conjunction with an inclinometer that senses local vertical. Distance traveled is measured by an odometer and by RF ranging to an active transponder on Surveyor when available. Triangulation by TV can be performed when well-defined objects are present.

Positive control of the vehicle at all times is essential for maneuvering the SLRV around irregularities and to steer along a desired path. This steering control is performed from the ground station by an operator-directed, computer-implemented procedure.

The control function is performed at the ground station operator's console with the aid of computer inputs. A small amount of control logic is also needed on the vehicle to convert the steering commands into control signals to the drive motors. The operator's console incorporates a television display on which the operator indicates the desired path; the computer determines and displays a predicted path, including the vehicle steering effects. This technique supplies feedback information to the operator for evaluation of the commands he has directed before the commands are actually sent to the vehicle.

5.3 DESIGN STATUS

The design analyses, tests, and demonstrations conducted during Phase I are summarized for each SLRV subsystem in Table 5-1. In addition, key areas of further study during Phase II are identified. The information contained in Table 5-1 is taken primarily from Volume III, Books 1 and 2.

[redacted]

	Structure & Materials	Mechanical & Electronic Components	Mobility	Surveyor Integration	Scientific Experiments	Navigation
DESIGNS AND ANALYSES COMPLETED	1. Design for weight, space, mounting, rigidity, and damping. 2. Aluminum alloy selected for primary structure. 3. Reviewed applicable SLRV materials for available data in this environment	1. Investigation of components presently in development. 2. Dynamic analysis established impact loads and overturning stability during deployment 3. Verified that all portions of the vehicle clear the Surveyor during deployment.	1. Lightweight, efficient track design. 2. Performance capability analysis of center pivot track. 3. Dynamic & Stability analysis of vehicle. 4. Traction drive mechanism performance analysis. 5. Life and reliability analysis of traction drive mechanism.	1. Determined spring loads required to deploy vehicle. 2. Dynamic analysis establishing impact loads & stability. 3. SLRV fit within Surveyor storage limits	1. Established a complete set of photogrammetry system error coefficients 2. Penetrometer probe fatigue problems and stress [illegible] side load 3. Data extrapolation [illegible] pads up to [illegible] cm diam. with one soil type	1. Selection of dead reckoning with RF ranging 2. Digital [illegible] aspect [illegible] 3. [illegible] 4. [illegible]
TESTS AND DEMONSTRATIONS COMPLETED			1. Feasibility of a four-tracked vehicle with prestressed rim 2. Feasibility of differential speed steering 3. Wheel speed control technique. 4. Atmospheric and vacuum tests of motor and transmission.		1. Photogrammetry experiments show that planned TV resolution is adequate 2. Photometer experiments	
RECOMMENDED FOLLOW-ON STUDIES	1. Detailed structural dynamics analysis. 2. Materials in lunar environment and RTG environment for use in SLRV.	1. Rotating or moving joints to avoid cold welding and lubrication problems. 2. Update component reliability data by tests made under simulated lunar environmental conditions. 3. Reliability test program.	1. Method for supporting the rim between idler and drive mechanism. 2. Optimize steering lock.	1. Deployment tests using a real impact surface to determine loads and stability. 2. Vibration of track strut combination to determine tie-down requirements.	1. Define adaptive techniques of image data collection as a function of terrain in order to minimize mission time. 2. Extend soil experiments to other types of soils under vacuum and high temperature conditions. 3. Investigate other (additional) soil instrumentation 4. "Quick look" technique for topography verification	1. [illegible] RF [illegible] and design 2. Development of high accuracy [illegible] 3. [illegible] of navigation [illegible] dynamics [illegible] analysis 4. Analysis and testing of sensor mechanical misalignments due to thermal and stress loads.

[redacted]

I

TABLE 5-1

STATUS OF 100-LB PRELIMINARY DESIGN

Television	Communication	Power Supply	Thermal Control	Ground Operations	Ground Support
1. Vidicon was selected as the primary sensor. 2. Digital TV modulation selected. 3. TV requirements established for mapping, navigation, and vehicle control. 4. The adequacy of fixed focus optics was established. Gimbal accuracy for triangulation ([illegible]arting)	1. Direct and indirect communication links were investigated showing advantage of direct link. 2. Tradeoff consideration of one versus three DSS investigated. 3. Use of PCM for all communication including video. 4. All solid state except TWT selected. 5. Omni antenna for command and TM high gain directional dish for video.	1. Survey of RTG manufacturers' capabilities and conceptual designs for SLRV. 2. Converter regulator unit designed.	[illegible] active techniques are suitable for transit, [illegible] day operation & [illegible] survival Established minimum [illegible] launch cooling requirements.	1. DSIF/SFOF computation requirements determined. 2. Detailed estimates of "Decision Time." 3. Selected use of Goldstone only for control (from SFOF).	1. Possible solution to RTG support and installation procedures. 2. Indicated general test and support problems associated with different gravity conditions.
400 line digital TV breadboard				1. Vehicle display/control concepts for discontinuous driving.	
1. Advanced TV sensors and optical mechanical scanners TV photometric calibration techniques Polarization and colorimetric filter analysis.	1. Investigate the improvement of reliability through additional redundancy within weight limitations.	Resolve RTG safety procedures with AEC. 2. Ba[illegible] power selection with an adequate design	[illegible] ability of various [illegible]gs with required [illegible] for lunar environment. 3. [illegible] metallic switches. [illegible] night operation.	1. Operator training requirements, procedures and facilities 2. Determine in detail, ability of observer to detect and identify lunar surface features via TV views. 3. Define the numbers and type of photogrammetric measuring equipment required to support the mission.	1. Determine solutions to test and support earth under gravity and correlation with lunar gravity

2

SECTION 6

RELIABILITY

6.1 RELIABILITY PROGRAM

The SLRV Phase I reliability program was comprised of the following activities:

1. Parametric studies of subsystem concepts to provide reliability trade-off criteria for system concept freeze.
2. Establishment of detailed reliability models for each subsystem, consisting of reliability block diagrams and associated mathematical equations.
3. Conduct of a failure mode, effect, and criticality analysis of each subsystem down to the part level to the extent possible. Results from the subsystem failure mode, effect, and criticality analyses were used in a computer program to obtain a criticality ranking from a system standpoint.
4. System and subsystem reliability predictions were made based on an average mission time obtained from the system evaluation computer program.
5. System and subsystem goals were established.
6. Maintainability of the vehicle system was studied as the concept and design were developed to ensure a system which would be maintainable from assembly through launch countdown.

6.2 RELIABILITY RESULTS

The SLRV reliability goal and prediction tree is shown in Figure 6-1. The reliability predictions are very conservative, since high-reliability parts were not employed in the initial design of all subsystems. Also, the

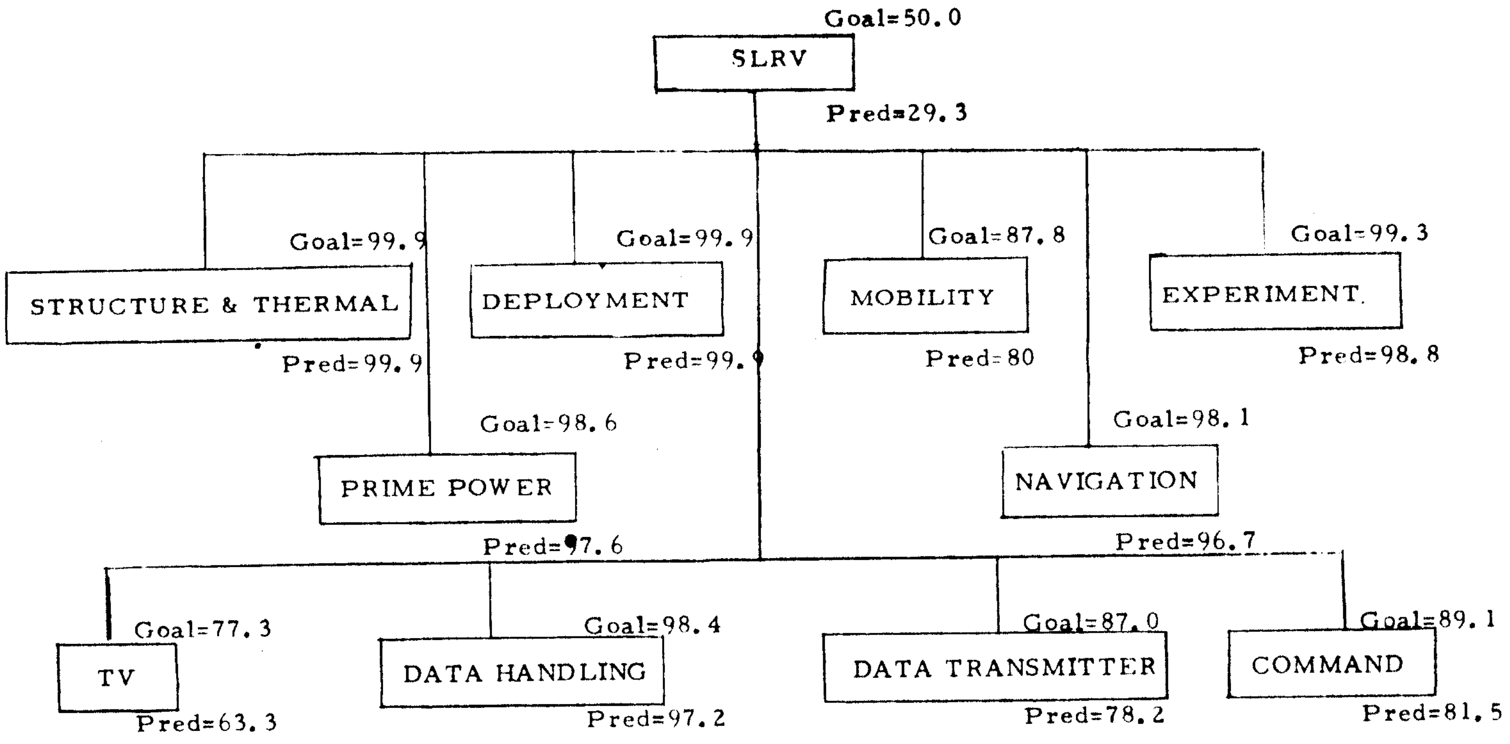

Figure 6-1 Reliability Goal and Prediction Tree

data shown are for a 4.5-month mission. The TV subsystem prediction of 63% could be increased considerably through the use of high-reliability parts.

6.3 CONCLUSIONS

The reliability analysis of the SLRV system during Phase I has resulted in the following conclusions.

1. The reliability goal of 0.50 for a mission period required to survey 19 landing points can be achieved with selective redundancy at a weight penalty of 1 lb. This goal can be surpassed with additional redundancy and more extensive use of high-reliability parts with an additional weight penalty of 3 lb.

2. The subsystems contributing most to system failure are TV, data transmitter, and mobility.

3. The three most critical items in the system are:

    a. The track in the mobility subsystem

    b. The vidicon tube in the TV subsystem

    c. The coaxial switch in the data transmitter

4. The computer evaluation program has provided a tool for reranking the criticality of parts whose failure does not cause mission abort but permits the mission to be completed in a degraded mode of operation. The effect on system reliability as a result of increased mission time is the factor employed in reranking the criticality of parts.

SECTION 7

PROGRAM RECOMMENDATIONS

The feasibility of the SLRV system and its potential contributions to the probability of LEM success justify an intensive development program aimed at early system operation. If possible, this development effort should be based on a system weight of at least 125 lb.

Additional studies that would contribute to the success of the SLRV program include:

1. Maximum integration and assignment of experiment priorities to various lunar programs. For example, it appears that several systems have nearly the same capabilities; others have only limited capability.
2. The addition of a limited terminal guidance capability to Surveyor. Such a capability would significantly increase the probability of SLRV primary mission success.
3. Laboratory investigations to expand our present knowledge of soil structures and dust under extreme vacuum. Such studies would support design of the SLRV and interpretation of the data its experiments and sensors obtain.
4. Inclusion on early Surveyor flights of test equipment related to critical SLRV subsystems (e. g., penetrometer, traction drive units, directional antenna, and communications system).
5. The development of a lightweight reliable beacon for use as a site marker.