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LAND LOCOMOTION LABORATORY

Report No. 8459

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FEASIBILITY STUDY OF A LEVERED VEHICLE (PART I)

CATALOGED

By

G. L. Macpherson

27 November 1962

Project No. ~~5510.~~11.82200

D/A Project No. DA-19-020-ORD-5729

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ACKNOWLEDGEMENT

This report is a result of work done for the Land Locomotion Laboratory, U. S. Army Tank Automotive Center, under Contract DA-19-020-ORD-5729. Dr. K. V. Smith, Dept. of Psychology, University of Wisconsin and Dr. T. Sheridan, of the Massachusetts Institute of Technology, reviewed the work and gave many valuable suggestions.

ABSTRACT

Engineering studies on the feasibility of a full-size, man-operated, levered vehicle have been conducted in three areas:

a. Establishment of preliminary performance
b. Analysis of perambulation
c. Human factors analysis

Results indicate that the concept is feasible within certain performance limits, and that an agility demonstrator is required for proof of feasibility.

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INTRODUCTION

1. BACKGROUND:

Based upon a proposal titled "Program for Development of a Levered Vehicle" dated 19 March 1962, which was submitted to the United States Army Ordnance Tank-Automotive Command, a feasibility study contract was awarded to the General Electric Company. This contract (DA-19-020-ORD-5729, dated June 29, 1962) contained the following work statement:

"Perform feasibility studies to initiate the development of a full-size, man-operated, levered vehicle. The work shall include the following:

a. Establishment of preliminary performance criteria.

b. Analysis of perambulation.

c. Human factors analysis."

This document is a final report.

The objectives of the program were met; the work performed is summarized as follows:

a. Studies were conducted in the three areas enumerated in the work statement.

b. Preliminary concepts and operational characteristics of a demonstrator vehicle were defined.

c. Certain problem areas were defined.

II. GENERAL CONCLUSIONS:

The engineering analyses performed under this contract indicate that a man-operated levered vehicle is feasible and results of this study indicate that further studies in vehicle analysis are justified. The study also indicates that a full-size agility demonstrator is required to prove feasibility.

SUMMARY

1. SCOPE OF STUDIES:

Feasibility studies to initiate the development of a full-size, man-operated, levered vehicle were performed. The studies included:

a. Analysis of Perambulation

b. Human Factors Analysis

c. Establishment of Preliminary Performance Criteria

The conclusion was that, within the scope of these three study areas, a demonstrational levered vehicle can be developed which man can control.

The study also confirmed the early recognition of the requirement for a full-size agility demonstrator with which feasibility can be established. The first generation of levered vehicles would serve primarily to demonstrate that man can control such a machine, and secondarily to investigate the feasibility of field equipment.

2. BASIC DESIGN PARAMETERS:

Work performed to date has established certain design parameters for the agility demonstrator. Basic considerations of such a man-machine system are as follows:

a. The system shall be machine, not man, limited.

b. Only the operator's inherent and acquired capabilities would be utilized to maintain active control.

c. The system need not be totally self=contained.

d. Have two articulate legs, functionally resembling human legs, in the order of 12 feet long.

e. Provide enough agility to respond adequately to the required operator's physical inputs.

f. Provide minimum, but sufficient, proprioceptive cues to the operator for maintaining balance and performing and evaluating limited locomotive tasks.

g. Provide the following locomotive capabilities:

(1) Stand still

(2) Step sideways

(3) Turn around

(4) Walk 3 to 10 mph

(5) Step up and down 2-1/2 foot high steps

The establishment of preliminary performance criteria confirmed early recognition of certain problem areas associated with vehicle mechanics. Solutions of these problems were considered outside the scope of this study (Reference: General Electric Company proposal for a "Program for Development of a Levered Vehicle", Section III-3), since they involved vehicle analysis. Solutions to some of these problems must be obtained before design specifications can be established. The conclusion of feasibility determined in this study justifies further studies in vehicle analysis.

DISCUSSION

1. ANALYSIS OF PERAMBULTAION:

The human locomotor mechanism was studied to ascertain the necessary kinetics for a man-operated machine. The conclusion was that for a useful degree of agility and balancing capability, a minimum of six motions for each leg will be required.

a. Taking a forward step requires three motions in one plane, namely, one at the hip, one at the ankle and one at the knee.

b. Adjusting the plane of the foot transversely to the terrain requires the fourth motion.

c. Swinging the leg outward at the hip for side to side balance requires the fifth motion.

d. A longitudinal rotation of the leg for turning left or right requires the sixth motion.

The most straightforward kinematic design for the levered vehicle would utilize the same angular excursions for walking that the operator uses. This would represent the simplest mechanism compatible with man's requirements for walking. The learning task of the operator is believed to be the simplest if the vehicle is geometrically similar to that of the operator's leg.

Statistics on average human walking were accumulated from literature to derive basic concepts for the levered vehicle. The average values for stride characteristics, forces, limb-joint rotations, velocities and accelerations, are summarized as follows:

a. Stride:

  (1) Unipedal contact time, 0.7 second.

  (2) Unipedal stride time, 0.4 second.

  (3) Bipedal contact time, 0.17 second.

  (4) Step length, 25 inches.

  (5) Cadence:

    (a) Level walk, 109 steps per minute.

    (b) Climb stairs, 90 steps per minute.

b. Principle forces, percent body weight:

  (1) Level walk:

    (a) Vertical load, 140 percent.

    (b) Aft shear load, 30 percent.

  (2) Climb stairs:

    (a) Vertical load, 135 percent.

    (b) Aft shear load, 15 percent.

c. Angular Rotation of Joints:

The rotational displacements of various human leg parts represent a very complex system. Rotations do not occur about simple axes, but rather around virtual axes which shift with angle and load. Considerations of a levered vehicle appear to necessitate simplifications in the leg motions. Based on these simplifications, the important angular displacements of the average human leg and the estimated values for the first generation agility demonstrator are presented in the following tabulation:

Joint:	Average Human	Demonstrator Vehicle
a. Hip		
(1) Forward rotation	130°	40°
(2) Aft rotation	50°	40°
(3) Abduction	53°	20°
(4) Abduction	31°	10°
(5) Lateral rotation	39°	45° *
(6) Medial rotation	34°	45° *
b. Knee flexion	160°	75°

c. Ankle

Ankle rotations are difficult to express in simplified terms since the axes are neither orthogonal, nor oriented in the substrate plane or plane of travel. However, for purposes of expressing angular excursions, the following will suffice:

	Average Human	Demonstrator Vehicle
(1) Dorsi flexion	35°	25°
(2) Plantar flexion	38°	25°
(3) Inversion	40°	10°
(4) Eversion	10°	10°
(5) Lateral rotation	23°	*
(6) Medial rotation	24°	*

*Whether rotation should occur at the hip or ankle has not been resolved since the location of rotation may influence vehicle control and dynamic characteristics.

d. Velocities and Accelerations

The angular velocities and accelerations of the human leg components vary widely with specific activities. For purpose of this study, only the minimum values compatible with the requirements of a demonstrational vehicle were considered. The knee bend appears to impose the most severe acceleration loading of the leg requirements. Acceleration values believed to offer sufficient agility for a test vehicle are as follows:

(1) Walking, unloaded leg, 40 to 50 radians/sec^2.

(b) Climbing stairs, 5 radians/second^2.

Standing still requires the constant application of corrective moments about the ankle and hip axes. Additional factors enter during locomotion because of the dynamic characteristics of the system. In addition to the corrective moments about the various axes, deliberate angular excursions must be introduced at rates compatible with system dynamics. <u>The successful levered vehicle must therefore, respond correctly to the operator's output, and in return provide him with accurate feedbacks in force, position and velocity</u>.

2. HUMAN FACTORS ANALYSIS:

a. General: The present concept of a bipedal levered vehicle assigns to man the function of primary control component of the system. In this capacity, man must receive and integrate the critical sensory inputs required for initiating the appropriate motor responses involved in the maintenance of posture and the performance of locomotion. In his normal environment, man has successfully demonstrated the ability to perform these complex sensory-motor tasks. He has convincingly shown this ability under conditions of normal sensory-motor functioning, as well as in cases where deviation from this situation exists, e.g., the blind, those with non-functional vestibular labyrinths, tabes dorsalis afflicted, and paraplegics fitted with prosthetic devices.

The basic function of a levered vehicle is to serve as an anthropomorphous selective response amplifier, governed by the normal motion responses of man. Such a system is feasible from the standpoint of a human operator if the vehicle portion of the system can (1) accurately follow and duplicate all of man's normal locomotor responses, and (2) provide no detectable reduction in feedback, nor distortion in feedback between the motion responses of the operator and the effectors of the vehicle. We do know from pathological cases such as previously mentioned, as well as from laboratory evidence, that man can compensate for and adapt to deviations from his normal sensory-motor-environment relations. The basic question then becomes, - to what extent can we cause deviations from basic locomotion patterns and feedback processes, and still expect the operator to perform the behavioral tasks of equilibrium and locomotion?

To provide an approach to the solution of these problems, the Human Factors analysis of levered vehicle feasibility was divided into three main sections, namely: (1) Formulation of a conceptual model of the nature of behavioral organization in human locomotion, (2) Compilation of a quantitative description of human locomotion, and (3) Consideration of the relation of these factors in determining systems feasibility.

b. Behavioral Organization in Human Locomotion. Human bipedal locomotion may be considered as being composed of three basic motion patterns, namely, the spatial, temporal, and intensity patterns. The spatial pattern concerns the geometric relationship of the position of the torso and limbs to the principal axes of the body. The temporal patterns deal primarily with the time characteristics associated with the different movements in walking, while the intensity pattern relates to the force factors encountered in moving the body through space and during contact with the ground. The integration of these three patterns provides the coordinated activity of locomotion.

Each locomotion pattern is composed of three functionally distinct component movements which may be referred to as (1) movements for postural support, (2) travel movements, and (3) manipulation - contact movements (Smith, 1962). Of fundamental importance to the successful operation of a levered vehicle, as well as to normal walking on the ground, is the maintenance of erect posture. The movements of postural support are the primary factors in each of the three motion patterns, and to a certain degree determine the character of the stride and contact movements of the foot.

There are two basic types of postural movements: (1) The dynamically compensatory movement of the head, arms, and torso which serve to maintain balance in stride by correcting for shifts in the center of gravity of the body, and (2) the direct regulatory postural motions of the feet and legs which serve to govern stride motion for the maintenance of balance. The travel or stride movement performs the dynamic action of twisting the body at the center of gravity to swing the leg along with the body, and the preparatory motion required before the foot contacts the ground. In addition, these movements perform the task of adjusting the direction of forward progress during walking. The contact movements serve in the maintenance of posture and constitute the landing and take-off action of the foot for the stride movements.

Essentially there are four types of space, time, intensity feedback - (1) feedback related to postural control of the center of gravity of the body, (2) ambulation feedback related to relative articulation of the limbs in the stride, (3) cutaneous feedback from the base of the foot as it is articulated with the terrain, and (4) visual, cutaneous and vestibular feedback related to directional control of locomotor orientation and shifting gait (Smith, 1962). Each of these feedback systems serve as error detectors between the actual space, time, intensity patterns of locomotion and the stimulus pattern of the sensory feedback produced by these movements. Compensatory response movements are based upon the comparison and integration on this information within the nervous system.

c. Feasibility of a Man-operated Levered Vehicle. The feasibility of a man-operated levered vehicle, from the standpoint of a human operator, depends on two basic factors. First, the vehicle effectors must be capable of approximating the basic patterns of human locomotion; second, the system must allow for a certain fidelity of feedback from motion movements. The critical factor in both instances is determination of the limits of acceptable performance, or in other words, the boundaries of allowable deviation from the characteristics of normal locomotion. Our present state of knowledge does not include definitive information concerning these deviation limits or their complex interaction. On the other hand, we have, in this feasibility analysis, (1) defined what we believe to be the basic parameters along which these deviations may occur, and (2) provided quantitative data on normal human locomotion to serve as reference points for these deviations. To arrive at a final statement of feasibility, the next logical step is fabrication of an experimental agility demonstrator. Such a device will aid in defining acceptable deviation limits and gaining insight into their interactions.

Analysis of the response characteristics of the human operator has lead us to the conclusion that placing a man 12 feet above the ground should not degrade his behavior. In fact, it may work to his benefit in some instances. For example, the response characteristic of the operator to acceleration shows that the threshold for detection of angular acceleration decreases with increased exposure time.

Since the angular acceleration of a falling man is inversely proportioned to its height, "a taller object will have a reduced angular acceleration at any angle and will therefore take longer to reach a given angle of tilt than the shorter object" (Ziegler, 1962).

A man in a levered vehicle has about two times longer exposure to acceleration during an impending fall, as compared to a man standing on the ground, and should therefore have increased probability of making a corrective balancing response. This response enhancement characteristic has important implications for the area of dynamic equilibrium.

Work conducted in our laboratory with ankle-articulated,thigh-terminated, nine foot stilts has demonstrated that man can very rapidly achieve the ability to attain and maintain both static and dynamic equilibrium at such heights. Probably of greater importance is the fact that it demonstrates his ability to adapt to deviations in his normal locomotor patterns and to degradation in his feedback mechanism.

In general, we may conclude that from the standpoint of a human operator, there is evidence that points to the feasibility of a levered vehicle. However, proof of feasibility may be justified only after experimental work on an agility demonstrator.

3. ESTABLISHMENT OF PRELIMINARY PERFORMANCE CRITERIA:

The concept of a bipedal levered vehicle is novel. It is novel because of its mode of control in that the machine is controlled by the muscular output of the operator's legs in a fashion not previously accomplished. This control feature is believed to offer significant advantages for off-the-road locomotion because the operator can maneuver such a vehicle over better than average sample of the terrain. The concept contains many untried and unproven principles in man-machine relationships. While design concepts and objectives can be derived through studies, proof of vehicle concepts and feasibility will only be derived through the development of a demonstrational vehicle.

Initial vehicle concepts and performance characteristics were established as guidelines for the Human Factors Analysis. Basic considerations for the demonstrational man-task and man-machine relationships included the following:

a. The system would be machine, not man, limited.

b. Only the operator's inherent and acquired capabilities would be utilized to maintain active control.

c. The system need not be totally self-contained.

d. The vehicle shall have two articulate legs, functionally resembling human legs. The legs shall be in the order of 12 feet long.

e. The control characteristics shall:

(1) Provide enough agility to respond adequately to the required operator's physical inputs.

(2) Provide minimum, but sufficient, proprioceptive cues to the operator for maintaining balance and performing limited locomotive evaluation tasks.

f. The vehicle shall have the following locomotive capabilities:

(1) Stand still

(2) Walk 3 to 10 mph

(3) Step sideways

(4) Turn around

(5) Step up and down 2-1/2 foot high steps

The guidelines listed above represented relatively rudimentary machine capabilities. However, they served to point to a number of limitations and problem areas. Some of the problem areas recognized in the study were the following:

a. Balance:

(1) Difficult to reproduce the subtle ankle motions man uses to maintain balance during unipedal contact.

(2) The demonstrator machine will have nothing comparable to arms or an upper torso to supply assistance in balancing.

(3) Achieving proper servo responses to match machine and operator characteristics.

(4) Effect of extraneous mechanism deflections.

b. Operator Control Harness:

(1) Sensitivity of the system to providing the proper location of pivot axes for motion pick off and for sensory feedback.

(2) Providing adequate latitudes in operator input/output factors.

(3) Filtering out undesirable operator motions (like motions resulting from sneezing!)

(4) Consideration of safety, comfort, fatigue, simplicity of entrance and egress and operator mental receptivity and reaction.

c. System mechanics:

(1) Vehicle weight and power.

(2) Mechanical resonances versus servo responses.

(3) Effect of external torques on spatial correspondence and force feedback ratios.

(4) Effects of various degrees of cross coupling in the servo system.

Engineering analysis of system concepts with respect to human factors requirements and preliminary performance criteria indicated certain limitations applicable to the demonstrator vehicle. The outstanding limitations emerging from this analysis were the following:

a. The prime mover, hydraulic pump and auxiliary electrical and electronic control equipment should be carried by an external means. Provisions must be included for ballasting the test vehicle to simulate weight and to determine its best location with respect to CG and the hip joint axes.

b. The power requirements for leaping and running do not appear to be justified for the first generation of vehicles.

c. Vehicle power and weight relationships appear to be critical and need definition. (Ref. Appendix C).

Results from the Human Factors Analysis showed that the over-all man-machine system must maintain (1) spatial correspondence, (2) temporal fidelity, and (3) appropriate proprioceptive intensity patterns. In order to achieve success, the vehicle must be compatible with the human operator in geometry, velocity and sensory feedback. These requirements are, therefore, the basis for design objectives, as follows:

a. The vehicle should be geometrically anthropomorphous.

b. The servo characteristics should be comparable to those achieved in the Handyman servomanipulator (See Appendix B). The following servo characteristics are estimated to be required by the levered vehicle:

(1) Stiffness: 4% compliance. This value is considered reasonable for servo design requirements and will provide good information to the operator.

(2) The peak force level to the operator should be no more than 50 pounds and not less than 25 pounds. For a 1500 pound vehicle, this would mean the force reaction ratio would be 45:1 to 90:1 (allowing for dynamic forces). Gain adjustments can be easily incorporated to allow gains of 20 to 150.

Force levels which are too high would cause operator fatigue. Force levels which are too low would reduce the erroneous forces reflected. Higher force reaction levels mean higher percentage of drift, viscous drag friction and inertia forces. However, higher force reaction gain provides the operator with finer sensitivity to increment changes in pedipulator forces.

A critical consideration regarding minimum peak force reaction is force saturation. The operator, overpowering the force reaction actuators, would lose spatial correspondence and, consequently, effective control of the pedipulator.

(3) The static velocity error coefficient must be a minimum of 325. A value of 1000 is ideal. (The gain at 1 radian-per-second should be between 50 and 60 db.) To keep the velocity error coefficient high, the first significant time constant should be kept low (about 1/40 second). For a hydraulic system this time constant is:

$$T_1 = \frac{M}{A^2 Hr} \text{ seconds.}$$

M is the equivalent mass, A is the piston area, and Hr is the pressure drop of the system with respect to flow rate of the oil. Within the frequency range that is of concern, the viscous drag for a 50# peak force is 1/20 pound for 1 radian-per-second, and for two <u>cycles</u> -per-second the viscous drag is 0.6 pounds. These are satisfactory values.

(4) The cross-over frequency of the system should be approximately 30 radians-per-second. The

combination of 50-60 db gain at 1 radian-per-second, critical time constant of 1/45 second, and this cross-over frequency, will provide a servo response speed in excess of what the operator will need. Anything faster would make it difficult to prevent the master harness from being dangerous.

(5) Static position error accuracy for this velocity servo is limited only by the position signal components and backlash. These conditions are kept well within the requirements of position accuracy of the servos. The critical limits of position component resulution and linkage backlash pertains to servo stability which is a more exacting requirement than positioning accuracy.

(6) Force drift (meaning a force reaction to the operator with no corresponding force on the slave servo), creates erroneous bias force and is a critical condition because it represents a continuous force to the operator, and even though it is a small amount, it represents a major factor in operator fatigue. This value of drift should be less than 1% of peak force. A value of 1/2 of 1% would be ideal. Special

arrangements had to be made to keep this drift value low for the <u>electrohydraulic</u> servo manipulator, "Handyman." It is expected that for the vehicle this anti-drift problem will not be as severe.

(7) Friction is critical also. It is critical because reflecting forces include friction of master and slave mechanisms. Friction decreases the threshold of force sensing. When all moving joints are designed to be rigid and operate on bearings, the friction is not detrimental. Thrust washers are not acceptable.

(8) The servo force threshold must be controlled to stay within a minimum value. This threshold value is influenced by position transducer resolution, backlash, servo hysteresis, bias force drift, and friction. This threshold should be held to be no more than 2% of peak force.

(9) Adjustments will be provided to: provide change in position and force gains; counterweight the bias forces due to dead weight of the legs, including the harness; force balance; amount of servo damping; and amplitude limits.

(10) It is anticipated that in the vehicle's leg, the force levels will be a complex combination and are not determined yet. The relative force levels of each motion must be carefully chosen to match the static and dynamic force requirements of the pedipulator. Likewise, the relative force levels to the operator must be proportional in respect to naturalness of human leg force proportions. This is with consideration of peak forces and forces with respect to angular positions of the linkages.

There will have to be compromises in choosing the best combination for force relationships. One very useful tool for compromising is some variation in the force reaction ratios for each servo loop.

Preliminary analysis indicates that the maximum leg thrust force required is 150% of the vehicle weight, regardless of the vehicle height.

(11) Amplitudes of motions have not been chosen, but have been estimated in the Discussion. It is important to allow sufficient range of motions so that the operator will not hit a

mechanical limit very often. Once a mechanical limit has been hit, force reflection to the operator for that motion is not correct. The only force felt is the operator force that holds the link against the mechanical stop. This is a precarious situation similar to the one in which the operator overpowers the force reaction actuator. Amplitudes (and kinematics) of the vehicle legs will be chosen to facilitate the basic goals of the agility demonstration. Sitting, getting up, running, stepping up and down large steps, will not be prime considerations for design of the demonstrator.

(12) Full scale harness models studied will help direct the choice of mechanics, kinematics, and amplitudes. Care must be taken in not falling into subtle traps such as allowing the harness mechanical knee linkage to lock in an over-center condition.

(13) Counterweighting is a relatively simple problem because of the general suspension arrangements, the high force ratio (or low percentage of force reflected), and the expected light weight of the operator harness arrangement.

Some bias force can be easily provided to compromise any dead weight forces that are objectionable.

Designing the control and servo system, within the boundaries of these specifications, will provide the operator with the capability of transmitting and receiving the required information and action. Figure 1 is a block diagram of the servo system relationships, and Figure 2 is a graph of the servo characteristics.

SERVO SYSTEM FOR LEVERED VEHICLE

Operator is an integral element within the servo loop.

Spatial Correspondence exists between the operator and vehicle feet (end effectors).

Kinesthetic force feedback to the operator is provided in a natural manner.

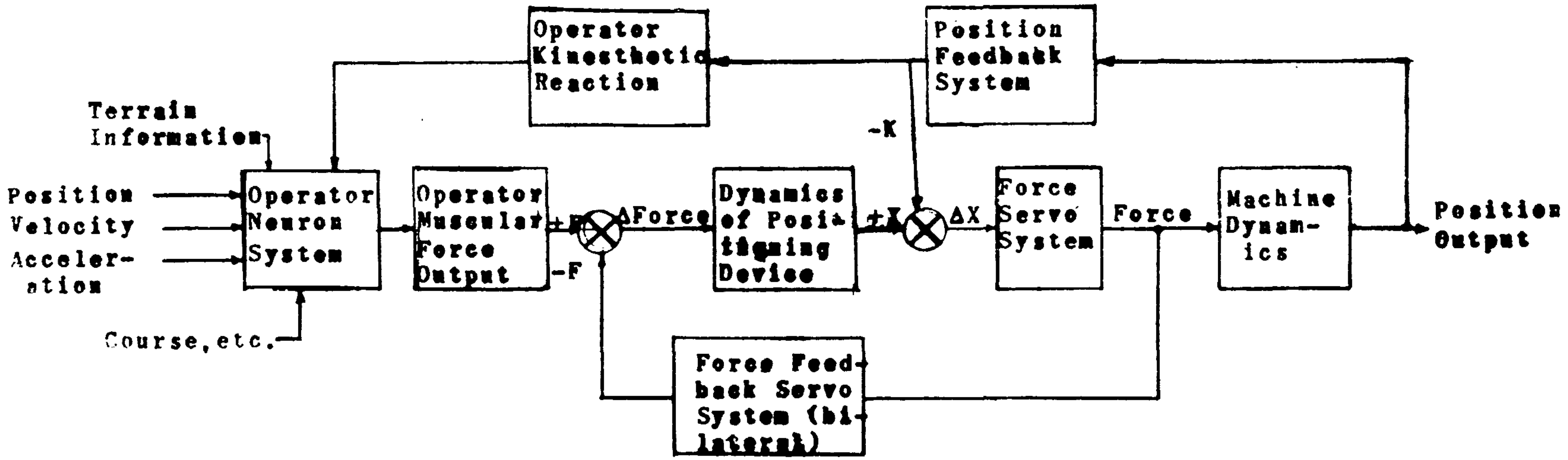
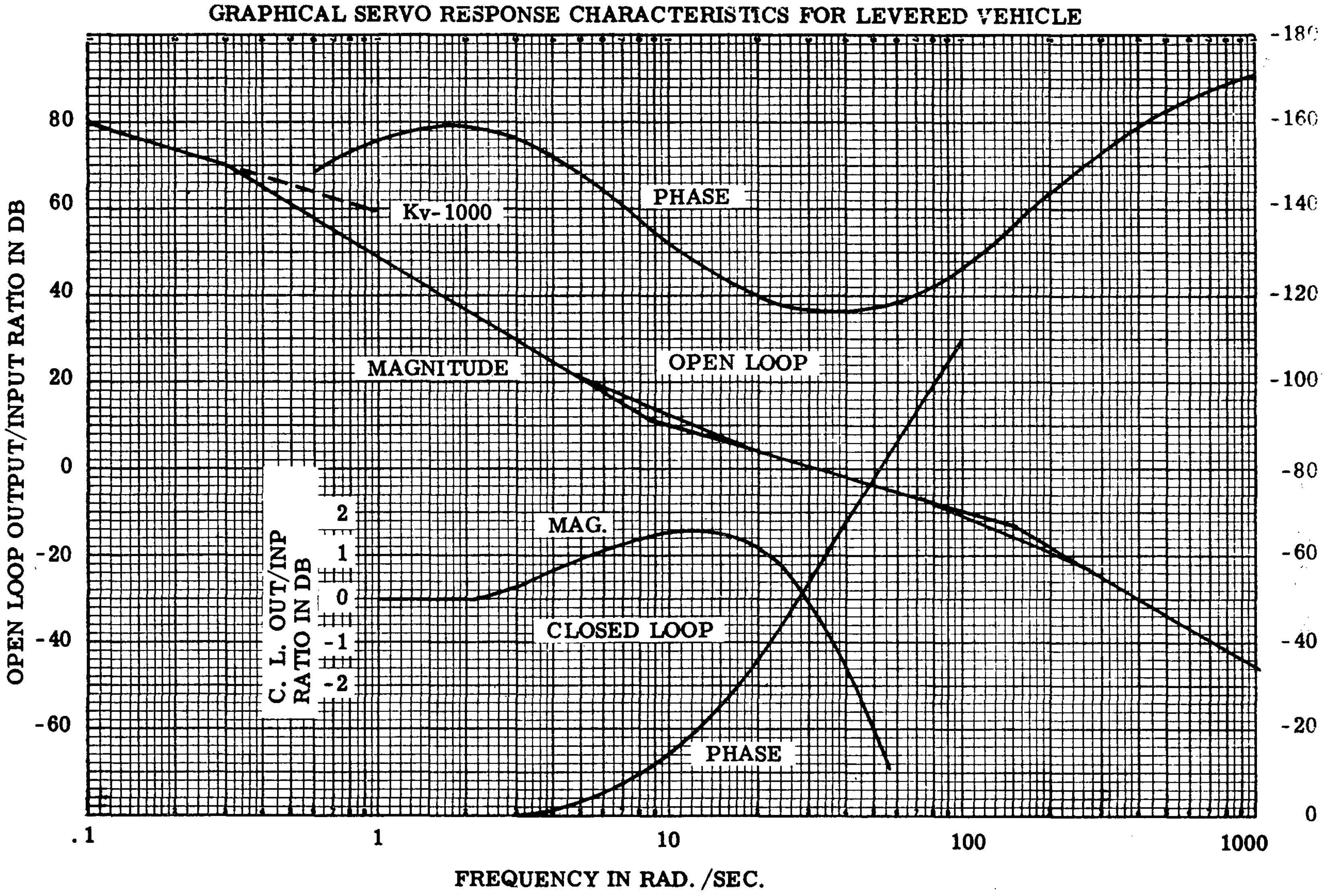


Figure 1. SERVO SYSTEM RELATIONSHIP



GRAPHICAL SERVO RESPONSE CHARACTERISTICS FOR LEVERED VEHICLE

Figure 2

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APPENDIX A

GLOSSARY OF TERMS

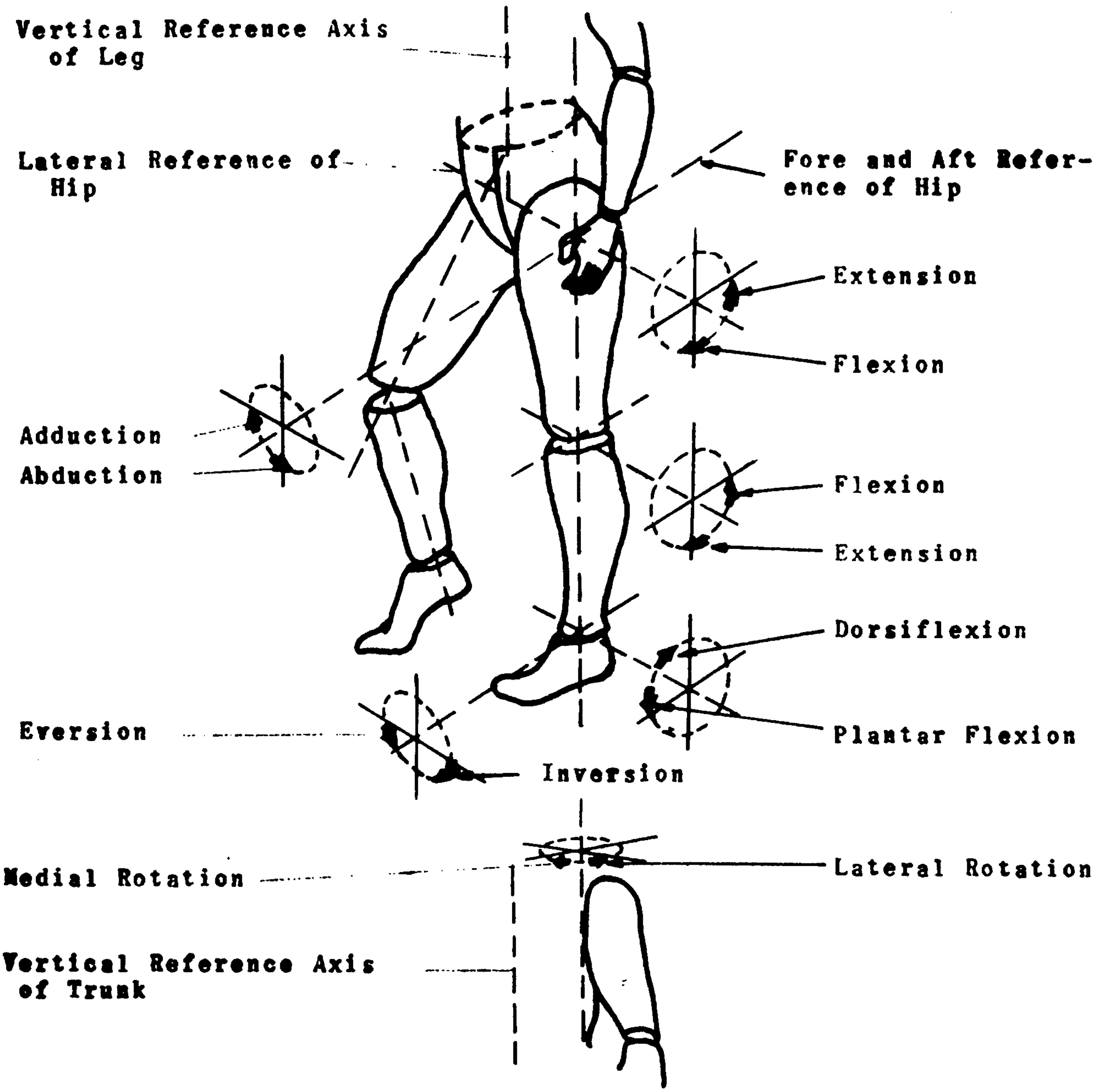
1. ABDUCTION: - The withdrawal of a part from the axis of the body. Of the foot: rotation of the foot outward on its own axis. To move away or to be away from the mid-line of the body. (For a part to be further away from the mid-line than normal).
2. ADDUCTION: - Any movement whereby a part is brought toward another or toward the median line of the body. A part of the body is nearer the mid-line of the body than normal when in adduction.
3. ANTERIOR: - Placed forward or to the front of a part; ahead.
4. DORSIFLECTION: - The movement of the foot in an anterior direction about a hypothetical axis passing transversely through the foot.
5. EXTENSION: - A straightening out, especially the muscular movement by which a flexed limb is made straight.
6. FLEXION: - The act of bending, the condition of being bent.

7. LATERAL: - Toward the outside. (opposite: Medial)

8. MEDIAL: - Toward the inside or center.

9. PLANTAR FLEXION: - The movement of the foot in a posterion direction about a hypothetical axis passing transversely through the foot.

10. POSTERIOR: - Placed behind or to the back of a part; behind.



GRAPHIC PRESENTATION OF GLOSSARY OF TERMS

APPENDIX B

CONSIDERATIONS FOR STEP HEIGHT

DEMONSTRATOR - STEP CLIMB

Weight of Demonstrator = W

Length of Leg = L

Weight of Leg = W_L

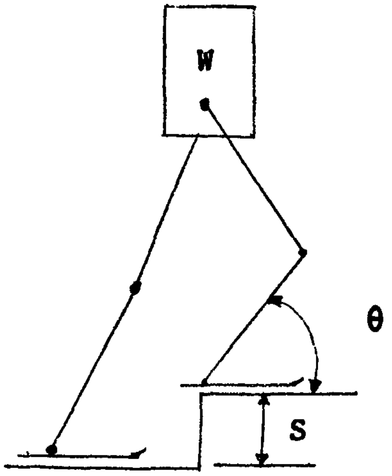
Weight of Body = W_B

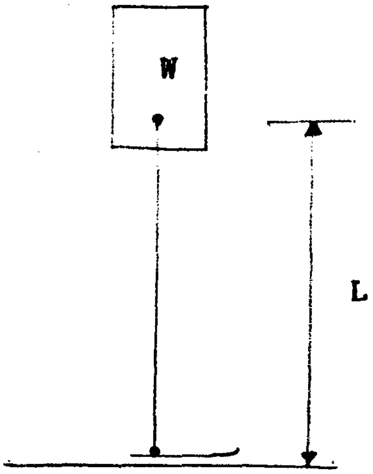
Angle Shank to Ground = θ

Assumed: C.G. of W always over pivot axis of ankle.

Upper and Lower Leg lengths are equal.

Step Height = S





$S = L - L \sin\theta = L(1-\sin\theta)$

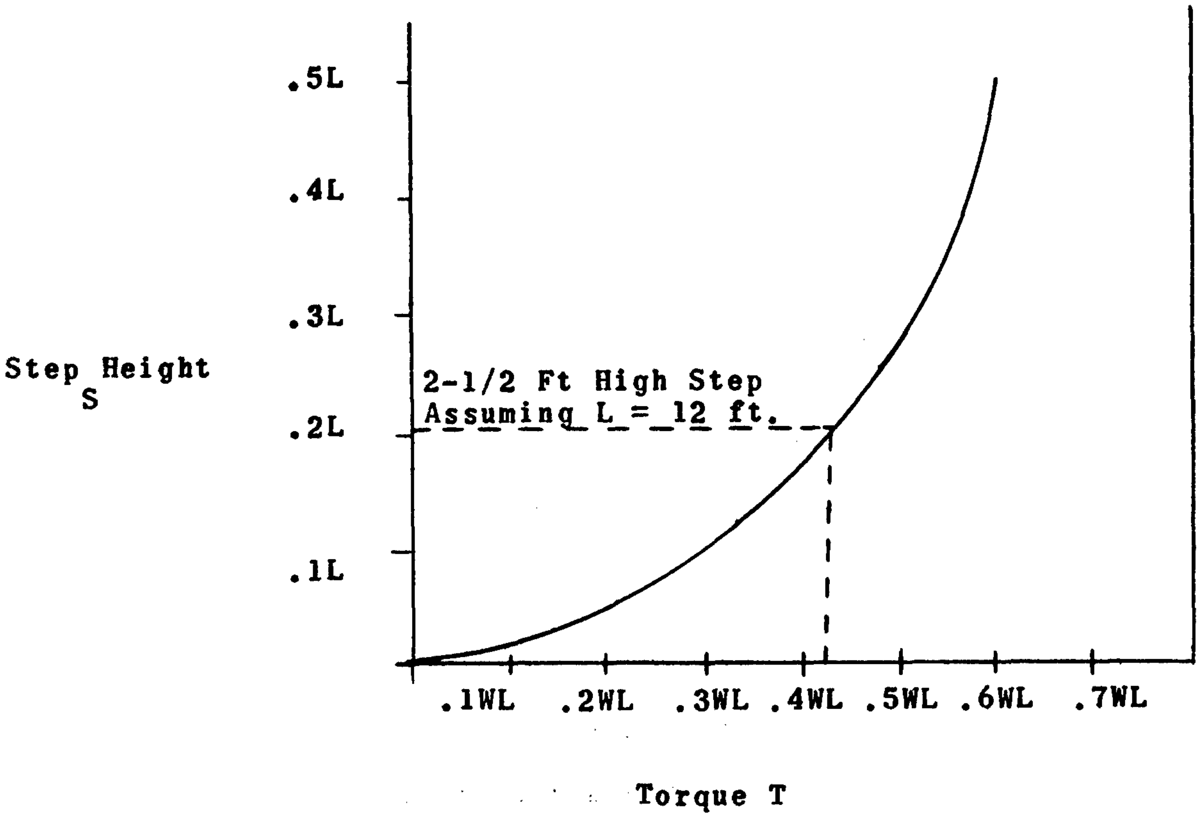
140% Max. body weight on step vertical

Torque at knee joint (Neglecting shear force)

$$T = 1.4W\frac{L}{2}\cos\theta = 0.7\,WL\cos\theta$$

DEMONSTRATOR - STEP CLIMB (Cont'd.)

θ	$1-\sin\theta$	S	$0.7\cos\theta$	T
30°	.5	.5L	0.605	.605WL
40°	.357	.357L	0.577	.577WL
50°	.234	.234L	0.45	.45WL
60°	.134	.134L	0.35	.35WL
70°	.06	.06L	0.24	.24WL
80°	.015	.015L	0.122	.12WL
90°	0	0	0	0



CONSIDERATION FOR STEP HEIGHT

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AUTHOR: George L. Macpherson
DATE: 27 November, 1962
REPORT NO: 8459
DEPT. of ARMY PROJ. NO.: DA-19-020-ORD-5729
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ABSTRACT CLASS: Unclassified
FILE: Levered Vehicles

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(1) Establishment of preliminary performance
(2) Analysis of perambulation
(3) Human Factors Analysis

Results indicate that the concept is feasible within certain performance limits and that an agility demonstrator is required for proof of feasibility.

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