EXTENDED DURATION ORBITER

TREADMILL

REQUIREMENTS DOCUMENT

<u>KRUG LIFE SCIENCES</u>

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Prepared By:

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Signature

Approved By:

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Signature

Concurrence By:

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Signature

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1 INTRODUCTION

Shuttle EDO missions will result in prolonged human exposure to a weightless environment. Of the numerous physiological consequences resulting from such exposure, there are several which can be altered by exercise including muscle atrophy, cardiorespiratory deconditioning and neuromuscular inefficiency. The EDO treadmill is intended to be utilized as a countermeasure to prevent these physiological problems by providing the capability for locomotion activity. The purpose of this document is to define the objectives and requirements of this device for use on Shuttle EDO missions.

2 PRIMARY DEVICE REQUIREMENTS

The EDO treadmill shall consist of three sub-components: a treadmill, a subject load device and a means to calibrate specified instrumentation. The treadmill is a device which allows locomotion at various speeds and grades on an endless looping belt. The subject load device provides stabilization of the treadmill user in a weightless environment by furnishing forces normal to the tread at a level equivalent to the subject's 1 g body weight. The subject load device shall attach to a Government furnished harness which the subject wears during exercise. A means to calibrate the instrumentation specified for the treadmill and the subject load device is required to insure accurate measurement of forces in a weightless environment. The three sub-components shall hence forth be referred to as the TM except when detail requirements of each component are described.

2.1 Treadmill:

The treadmill shall allow locomotion at various speeds and grades on an endless looping belt. It shall, as a minimum, provide for and meet the following requirements:

2.1.1 Running Surface:

The tread surface which the subject can run on shall meet the following dimensional minimums:

1) Width: 13 inches (33.0 cm)
2) Length: 44 inches (111.8 cm)

2.1.2 Operational Modes:

The treadmill shall be designed to provide the following operational modes for exercise training and testing in both 0-g and 1-g environments:

2.1.2.1 Motor Driven:

A motor shall be incorporated to drive the tread at speeds ranging from 2.5 to 10.0 miles per hour with a 180 lb. subject at 0 percent grade. The treadmill shall allow an infinite selection of speed within the defined range. The accuracy of the selected speed (averaged over one minute interval) shall be within +/- 0.3 miles per hour.

2.1.2.2 Passive:

The device shall be functional without the motor drive and allow a 180 lb. subject at 15 percent grade to drive the tread at speeds ranging from 2.5 to 10.0 miles per hour. The treadmill shall allow an infinite selection of speed within the defined range. The accuracy of the selected speed (averaged over one minute interval) shall be within +/- 0.3 miles per hour.

2.1.3 Inertia:

The treadmill shall have an inertia equivalent to at least the minimal inertia setting of the MKII Boilerplate treadmill. In terms of equivalent mass, this is approximately equal to 3.9 slugs when theoretically determined (ref. *MDSSC Report II-2: MKII Prototype and Boilerplate Treadmill Resistance and Inertia Evaluations*). The MKII Boilerplate treadmill shall be supplied for evaluation during the design of the EDO TM.

2.1.4 Running Board:

The treadmill shall provide a running board to stand upon on the left and right sides of the user, immediately adjacent to the tread. The running boards will be utilized to support the user while under load by the subject load device. Each running board shall be a minimum of 1.5 inches (3.8 cm) wide extending the length of the treadmill and allow the user to stand on it while the tread is still in motion.

2.1.5 End Plate:

The treadmill shall provide an end plate to stand upon in front and in back of the user, immediately adjacent to the tread. The end plates will be utilized to support the user while under load by the subject load device. Each end plate shall be a minimum of 3.0 inches (7.6 cm) wide extending across the width of the treadmill.

2.1.6 Hand Rail:

The treadmill shall provide a hand rail in front of the user for support during exercise.

2.1.7 Interface to Orbiter:

The treadmill shall be designed to be mounted to the middeck floor, mating with four AN7516 Cargo Airplane Tie Fittings. NASA shall provide the necessary interface drawings.

2.1.8 Instrumentation:

The instrumentation in the treadmill shall provide for measurement of the foot-ground reaction force normal to the tread surface. An analog interface shall be provided to allow NASA and/or KRUG to amplify and acquire the generated signal. The instrumentation, as a system, shall meet the following requirements:

Range:	0 to 1000 lbs
Overload capacity:	1500 lbs
Accuracy:	+/- 1 percent full scale range
Compensated temp.:	65 to 95 degrees F
Temp. zero:	0.1 percent full scale range per degree F
Temp. span:	0.1 percent full scale range per degree F
Frequency response:	(+/-2 dB from 0 to 45Hz)

2.2 Subject Load Device:

The subject load device shall provide stabilization of the user in a weightless environment and provide subject forces normal to the tread at a level equivalent to the subject's body weight. The subject load device shall meet, as a minimum, the following requirements:

2.2.1 Load Range:

The subject load device shall load the subject with a force normal to the tread with a range of 90 to 220 lbs.

2.2.2 Load Variation:

The device shall not vary in the applied load by more than five (5) percent of full scale range over a distance of 1.5 inches (3.8 cm) at a frequency of 3 Hz.

2.2.3 Subject Accommodation:

The subject load device shall accommodate users with dimensions ranging from a fifth percentile female to a ninety-fifth percentile male. Anthropometric and other related data is available from *NASA-STD-3000, Volume I MAN-SYSTEMS INTEGRATION STANDARDS.*

2.2.4 Subject Interface:

The subject load device shall provide a two point attachment to the subject in the sagittal plane at anterior and posterior locations. The subject load device shall allow the subject to move the attachment point a minimum of 6.0 inches (15.2 cm) to allow for differences in height between subjects. The attachment mechanism shall be defined by NASA at the Preliminary Design Review.

2.2.5 Instrumentation:

The instrumentation provided to determine the average subject load parallel to the tread in the anterior and posterior directions of the subject, shall meet the requirements stated in this section. The instrumentation shall be designed to measure the horizontal component of force of the forward and aft connecting means between the subject load device and the subject harness. Listed below are the requirements for the forward and aft load cells separately:

Range:	0 to 150 lbs
Overload capacity:	225 lbs
Accuracy:	+/- 1 percent full scale range
Compensated temp.:	65 to 95 degrees F
Temp. zero:	0.1 percent full scale range per degree F
Temp. span:	0.1 percent full scale range per degree F

2.3 Means for Calibration:

The means for calibration shall be provided to allow calibration of the TM instrumentation in a weightless environment. It shall be designed to provide baseline standards for expected load conditions and verify the instrumentation requirements specified in this document except where deviations are allowed as specified below:

2.3.1 Instrumentation Package:

The calibration device shall provide calibration of the instrumentation measuring the foot-ground reaction force. The device shall provide a load of at least 20 percent of the full scale range of the foot-ground reaction force instrumentation.

2.3.2 Subject Load Device:

The calibration device shall provide calibration of the instrumentation measuring the horizontal component of force supplied by the subject load device.

2.4 General Device Requirements:

The TM shall meet the following general requirements:

2.4.1 Control:

The subject shall be able to vary speed and percent grade by a control panel accessible during exercise and allow the subject to make changes while continuing to exercise.

2.4.2 Control Interface:

Simple mechanical or electronic controls, with mechanical and electrical interfaces that facilitate replacement without requiring other changes to the system, are required. The user controls must be easily accessible to the user while exercising.

2.4.3 Safety:

The TM shall provide an emergency stop switch which will immediately disconnect the power supply to the motor when operating in the motor driven operational mode. The switch shall be remotely operated and is intended to be attached to the harness by means of a quick release fastener.

2.4.4 Instrumentation:

All instrumentation sensors shall be commercially available and interchangeable.

2.4.5 Data Display:

The following information shall be available to allow the user to easily monitor his/her performance throughout exercise. Information shall be available in units shown below:

1) Elapsed time - hours, minutes, seconds
2) Tread speed - miles per hour (accuracy: 0.1 miles per hour)
3) Average load exerted on subject by subject load device - lbs
4) Tread revolution counter - revolutions (not required to be in a location such that the user can view counter during exercise but shall be externally visible)

2.4.6 User Generated Loads:

The TM shall be designed to support the user generated forces. During operation, the tread and support structure shall be designed to withstand transient loads equivalent to five (5) times body weight in one g of the heaviest expected subject. The weight of the heaviest expected subject shall conform to *NASA-STD-3000, Man-System Integration Standards Volume I.*

2.4.7 Facility:

2.4.7.1 General Stowage and Weight:

The TM shall be designed to utilize two stowage locations: the middeck floor and a single middeck locker. The portion of the TM which mounts on the middeck floor during launch and landing shall not exceed 75 lbs. and its center of mass shall not exceed eight (8) inches (20.3 cm) in height above the floor. Additional parts of the TM may be stowed in a single middeck locker. Parts stowed in this locker shall fit inside a large stowage tray with the dimensions defined in section 3.0 of NASA document *NSTS 21000-IDD-MDK, Shuttle/Payload Interface Definition Document for Middeck Accommodations.* Additionally, parts of the TM stowed in this locker must conform to the weight limitations defined in the aforementioned document.

The Government furnished harness will also be stowed in the middeck locker. Size and weight information on this harness will be provided at the Preliminary Design Review.

2.4.7.1.1 Launch and Entry Stowage:

The portion of the TM mounted on the middeck floor for launch and entry shall not interfere with the sleep station or orbiter wall. Additionally, there shall be no interference with mission specialist seat number seven (7) or with supporting biomedical equipment. NASA shall provide the necessary interface drawings.

2.4.7.1.2 Orbit Stowage:

The TM shall allow for the opening of the forward middeck lockers and not interfere with mission specialist seat number five (5). NASA shall provide the necessary interface drawings.

2.4.7.1.3 Stowed Dimensions:

The portion of the TM mounted on the middeck floor during launch and landing shall not exceed the following allowable volume:

1) Height: 12 inches (30.5 cm)
2) Width: 18 inches (45.7 cm)
3) Length: 52 inches (132.1 cm)

<u>2.4.7.2 Power:</u>

The device shall be designed to operate on only one of two available power sources:

1. 115 v AC (400 Hz, 3 phase, up to 3 amps per phase).
2. 28 VDC with a maximum allowable power shall be equal to or less than that specified in NASA document *NSTS 21000-IDD-MDK, Shuttle/Payload Interface Definition Document for Middeck Accommodations*.

A power profile shall be furnished that identifies power requirements during operation under maximum conditions. NASA shall provide the necessary interface power supply connectors.

<u>2.4.7.3 Assembly and Disassembly:</u>

The device should be easily disassembled and reassembled for stowage and operation by one person. Activation of the system shall require less than 5 minutes. Tethered fasteners are required for parts which must be assembled or disassembled on orbit.

3 APPLICABLE DESIGN REQUIREMENTS

The TM design shall conform to all aspects of NASA document *NSTS 21000-IDD-MDK, Shuttle/Payload Interface Definition Document for Middeck Accommodations* in regard to physical interfaces, structural interfaces, environmental conditions, thermal interfaces, electrical power interfaces, electromagnetic compatibility and electrical wiring interface.

3.1 Materials:

The materials specified in the design of the TM shall meet the requirements of *JSC-SE-R-0006B, NASA/JSC Requirements for Materials and Processes.*

3.1.1 Traceability:

The TM shall be manufactured such that all materials shall be certified as traceable to vendor.

3.1.2 Selection:

The materials utilized in the design of the TM shall conform to the following selection and compatibility requirements:

3.1.2.1 Metallic:

Metallic materials shall meet the general requirements of *JSC-SE-R-0006B, NASA/JSC Requirements for Materials and Processes.*

3.1.2.2 Nonmetallic:

Nonmetallic materials shall meet the requirements of *JSC 02681, Criteria for the Orbiter Vehicle Nonmetallic Materials Design Guidelines and Test Data Handbook.*

3.1.3 Flammability and Offgas:

The materials selected for use in the design of the TM shall meet the requirements of *NHB 8060.1B, Flammability, Odor and Offgassing Requirements and Test Procedures for Materials in Environments that Support Combustion.*

3.2 Load Limits:

A stress analysis and supporting documentation shall be delivered that demonstrates the TM will withstand the following load conditions:

3.2.1 Flight:

To meet the objectives of a Shuttle exercise device, the TM shall be designed to withstand the operational inertia loads, the emergency landing loads and random vibration exposure as defined in section 4.0 of NASA document *NSTS 21000-IDD-MDK, Shuttle/Payload Interface Definition Document for Middeck Accommodations.*

3.2.2 Reduced Gravity and Ground-based Testing:

Any structures designed to support or mount the TM during reduced gravity and ground-based testing shall be designed to withstand the structural loads and floor loading as defined in section 5.0 of NASA document *JSC-22803, JSC Reduced Gravity Program User's Guide.*

3.3 Safety Factor:

The design of all structures shall assure an ultimate factor of safety of greater than 1.4 under the load conditions defined in this document.

3.4 Electronics:

The design and manufacture of all electrical components and vendor supplied items must conform to the requirements of *NHB 5300.4*. Additionally, the TM must conform to electromagnetic interference limits specified in *SL-E-0002, EMI*.

3.5 Noise:

The maximum continuous sound pressure levels shall not exceed 70 dB measured one foot from the noise radiating surfaces. This test shall be administered with a 180 lb. subject running at 5 miles per hour on a 15 percent grade.

3.6 Maintainability:

A schedule of maintenance shall be provided identifying required procedures and methods to maintain device reliability.

3.6.1 Standard Hardware:

Standard commercially available hardware shall be used wherever possible to simplify servicing and reduce acquisition time and overall cost, including repair cost.

3.6.2 Reliability:

Identification of limited life items and a schedule of preventative maintenance or item replacement shall be provided.

3.6.3 Wear:

Portions of the system subject to wear or deterioration by body contact shall be readily cleanable and easily replaceable.

3.7 Safety:

The TM design shall maximize the safety of all personnel, including subjects, trainees, instructors, and maintenance people.

3.8 Environmental:

3.8.1 Ground-based Operation:

All portions of the system shall be suitable for use in a standard air conditioned environment, with the ambient temperature in the range of 18-25 degrees C and relative humidity in the range of 50% (+/- 25%).

3.8.2 Shuttle-based Operation:

The TM design shall be compatible for use in the Shuttle Middeck and shall meet the requirements of the environmental conditions specified in NASA document *NSTS 21000-IDD-MDK, Shuttle/Payload Interface Definition Document for Middeck Accommodations.*

3.8.3 Storage and Transportation:

The system shall be designed for storage and transportation by standard commercial procedures. No special protective measures shall be required other than box and crate commercial methods.

4 DOCUMENTATION AND TRAINING

4.1 Documentation:

All hardware developed for exclusive use on the TM shall be fully documented to facilitate acceptance testing, repair, calibration, modification, and use by personnel at NASA/JSC. Reproducible engineering drawings of all hardware and all vendor supplied drawings shall be provided, and shall be prepared in accordance with commercial standards. A complete schematic diagram of all electronic boards and connectors shall be provided.

4.2 Training:

Training shall be provided at NASA/JSC for:
- A) Exercise use
- B) Calibration and routine maintenance

5 REVIEWS

Periodic reviews by KRUG, NASA and NASA-designated personnel will be required during development of the TM. The following reviews, and others if required by the aforementioned parties, shall be conducted:

5.1 Preliminary Design Review (PDR):

After details of the system design are 10% - 20% complete, a PDR will be held at NASA/JSC to review the design and to avoid any potential conflicts with KRUG or NASA requirements. KRUG shall organize the PDR and will present the design details supplied by the TM subcontractor, however, the TM subcontractor shall be in attendance to answer questions and provide additional detail information upon request.

5.2 Critical Design Review (CDR):

After details of the system design are 90% complete, but before significant work is performed on actual fabrication, a CDR will be held at NASA/JSC to thoroughly review the design. KRUG shall organize the CDR and will present the design details supplied by the TM subcontractor, however, the TM subcontractor shall be in attendance to answer questions and provide additional detail information upon request.

5.3 Periodic Progress Reports:

Progress reports will be written and delivered to KRUG on a monthly basis. The written reports will detail progress, problems and problem solutions.

5.4 Pre-delivery Performance Demonstration:

A pre-delivery performance demonstration will be performed to demonstrate the function of the TM. This demonstration shall be used to identify problems which need to be corrected before acceptance testing. Documentation will be reviewed in conjunction with this demonstration. KRUG/NASA personnel will participate as operators and trainees.

5.5 Acceptance Testing:

After delivery to NASA/JSC in Houston, the system will be thoroughly tested to ensure that it performs according to contract specifications. Delivery shall not be considered to be complete until all the specified documentation is available and acceptable. An Acceptance Test Plan, written by KRUG, shall be delivered at PDR which specifies Acceptance Tests to be performed, the resources required to perform testing and the requirements to be verified. The Acceptance Test Procedure to be used for official testing, written by NASA/KRUG, shall be delivered at CDR.

6 DELIVERABLE CONFIGURATION:

The TM shall, at a minimum, consist of the following deliverable items:

6.1 Complete hardware package:

Complete TM meeting the requirements defined in this document as well as training on operations and maintenance.

6.2 Complete hardware documentation:

This includes list of materials, vendor component lists, engineering drawings and pre-delivery performance test data.

7 APPENDIX: APPLICABLE NASA DOCUMENTS

JSC-SE-R-0006B NASA/JSC Requirements for Materials and Processes.
JSC 02681 Criteria for the Orbiter Vehicle Nonmetallic Materials Design Guidelines and Test Data Handbook.
JSC-22803 JSC Reduced Gravity Program User's Guide.
MDSSC Report II-2: MKII Prototype and Boilerplate Treadmill Resistance and Inertia Evaluations. Exercise Countermeasure Facility, Crew Health Care System, McDonnell Douglas Space Systems Company, November 12, 1990.
NASA-STD-3000 Man-System Integration Standards Volume I.
NHB 5300.4 (1D-2) Safety, Reliability, Maintainability, and Quality Provisions for the Space Shuttle Program.
NHB 5300.4 (3A1) Requirements for Soldered Electrical Connections.
NHB 5300.4 (3G) Requirements for Interconnecting Cables, Harnesses, and Wiring.
NHB 5300.4 (3H) Requirements for Crimping and Wire Wrap.

NHB 5300.4 (3I) Requirements for Printed Wiring Boards.
NHB 5300.4 (3J) Requirements for Conformal Coating and Staking of Printed Wiring Boards and Electronic Assembles.
NHB 5300.4 (3K) Design Requirements for Rigid Printed Wiring Boards and Assemblies.
NHB 8060.1B Flammability, Odor and Offgassing Requirements and Test Procedures for Materials in Environments that Support Combustion.
NSTS 21000-IDD-MDK Shuttle/Payload Interface Definition Document for Middeck Accommodations.
SL-E-0002, EMI.

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TREADMILL STUDY