Abstract – Audio Development Laboratory (ADL) User Test Planning Guide

Test process, milestones and inputs are unknowns to first-time users of the ADL. The User Test Planning Guide aids in establishing expectations for both NASA and non-NASA facility customers. The potential audience for this guide includes both internal and commercial spaceflight hardware/software developers. It is intended to assist their test engineering personnel in test planning and execution. Material covered includes a roadmap of the test process, roles and responsibilities of facility and user, major milestones, facility capabilities, and inputs required by the facility. Samples of deliverables, test article interfaces, and inputs necessary to define test scope, cost, and schedule are included as an appendix to the guide.

Audio Development Laboratory (ADL)

User Test Planning Guide

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas 77058

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1.0 Introduction

The Johnson Space Center (JSC) has created and refined innovative analysis, design, development, and testing techniques that have been demonstrated in all phases of spaceflight. JSC is uniquely positioned to apply this expertise to components, systems, and vehicles that operate in remote or harsh environments. We offer a highly skilled workforce, unique facilities, flexible project management, and a proven management system.

1.1 Purpose

The purpose of this guide is to acquaint Test Requesters with the requirements for test, analysis, or simulation services at JSC. The guide includes facility services and capabilities, inputs required by the facility, major milestones, a roadmap of the facility's process, and roles and responsibilities of the facility and the requester. Samples of deliverables, facility interfaces, and inputs necessary to define the scope, cost, and schedule are included as appendices to the guide.

1.2 Facility Availability

JSC test facilities are available for the National Aeronautics and Space Administration (NASA), other government agencies, and commercial requesters. We have developed user-friendly agreements to streamline business relationships and are eager to share our unique facilities and expertise. We invite your inquiries regarding application or adaptation of our capabilities to satisfy your special requirements. Briefings on general or specific subjects of mutual interest can be arranged at JSC or at your business site.

1.3 Inquiries

General inquiries regarding the use of JSC facilities should be directed to:

JSC Engineering Directorate
Johnson Space Center
2101 NASA Parkway, Houston, TX 77058
Phone: 281-483-8991
E-mail: beth.a.fischer@nasa.gov

Inquiries regarding the use of the Audio Development Laboratory (ADL) should be directed to:

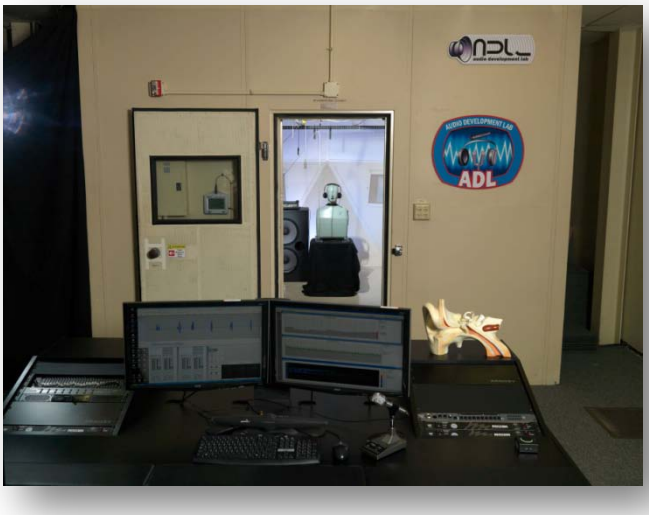
Andy Romero
Audio Development Laboratory Manager
Johnson Space Center
2101 NASA Parkway, Houston, TX 77058
Phone: 281-483-0159
E-mail: andy.romero-1@nasa.gov

Please refer to the Engineering Services Web site, http://www.jsceng.nasa.gov, for additional information and general inquiries about test, analysis, and simulation capabilities at JSC.

1.4 Audio Development Laboratory

The Audio Development Laboratory (ADL) consists of acoustic test facilities and supporting equipment for testing and development of audio communications and electro-acoustic systems and equipment. The ADL provides an acoustic test environment utilizing a reverberation chamber, anechoic chamber, and quiet room.

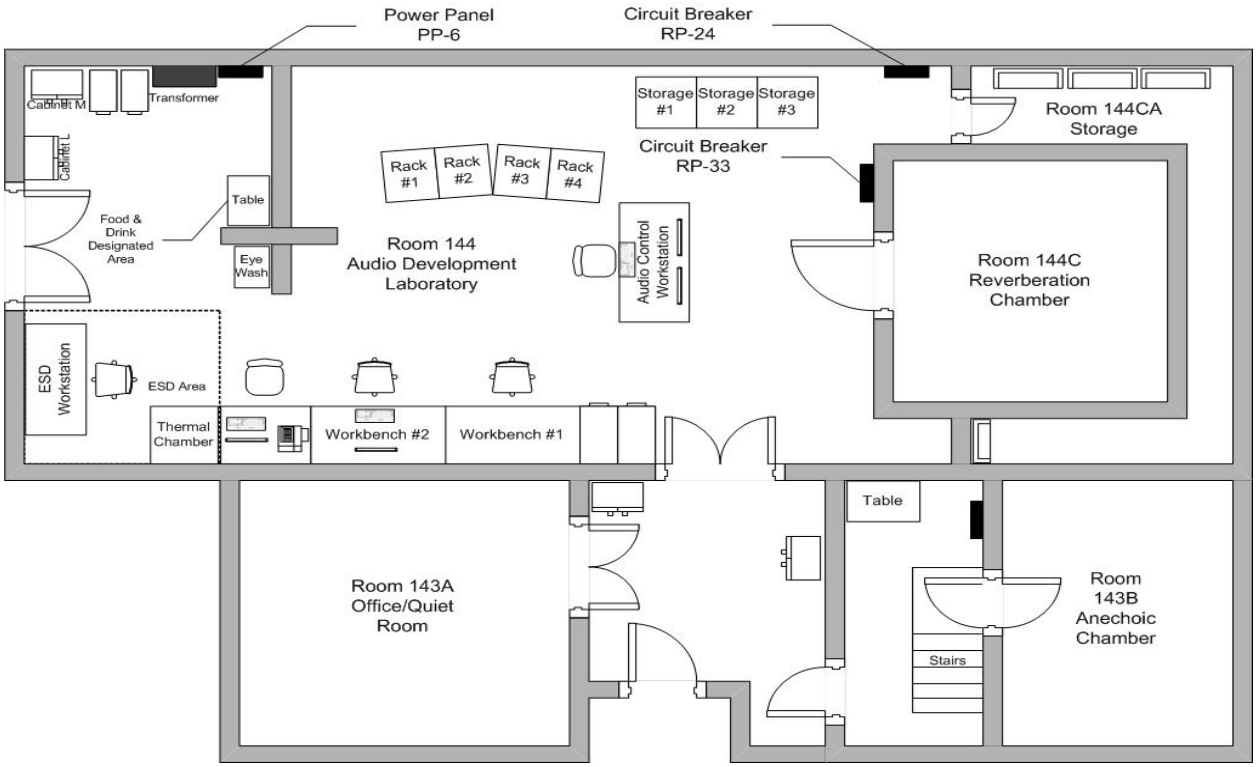
Services Provided
• Development, engineering evaluation, and acceptance testing of electro-acoustic and audio processing equipment, including earphones, microphones, headsets, audio codecs, and audio distribution systems • Audio and acoustic research and development, including acoustic-based sensors, speech synthesis, speech recognition, and emerging voice technologies • Development of audio communication equipment



Capabilities		
Reverberation Chamber	Provides uniform simulated acoustic environments for performance testing electro-acoustic devices, such as earphones with passive noise attenuation and noise canceling microphones	
	Dimensions	15′ x 8′ (pentagonal shaped volume to ensure a diffuse-acoustic environment)
	Sound Pressure Level (SPL)	125 dB SPL 30 to 500 Hz 115 dB SPL 500 to 8 kHz
Anechoic Chamber	Provides a free field acoustic noise environment for testing microphone, earphone, and loudspeaker performance and characterizing acoustic emission sources	
	Dimensions	15′ x 15′ x 15′
Quiet Room	Provides a low acoustic noise environment for audio recording and subjective audio performance testing	
	Dimensions	16′ x 16′ x 16′

2.0 Facility Layout

The ADL, located on the first floor of JSC Building 44, includes four facilities interconnected with cabling for test signals and control. Room 144 is the main laboratory, which includes several test racks containing audio, speech, and signal analyzers; digital audio recorders; power amplifiers; data acquisition sytems; and general test equipment. Signals are routed between the main laboratory racks, the other facilities, and the main laboratory test benches via an audio crosspoint matrix. The reverberation chamber is designated as room 144C and is located within the main laboratory. The quiet room and anechoic chamber, rooms 143A and 143B, are satellite facilities located adjacent to the main laboratory.



Physical Layout of Audio Development Laboratory

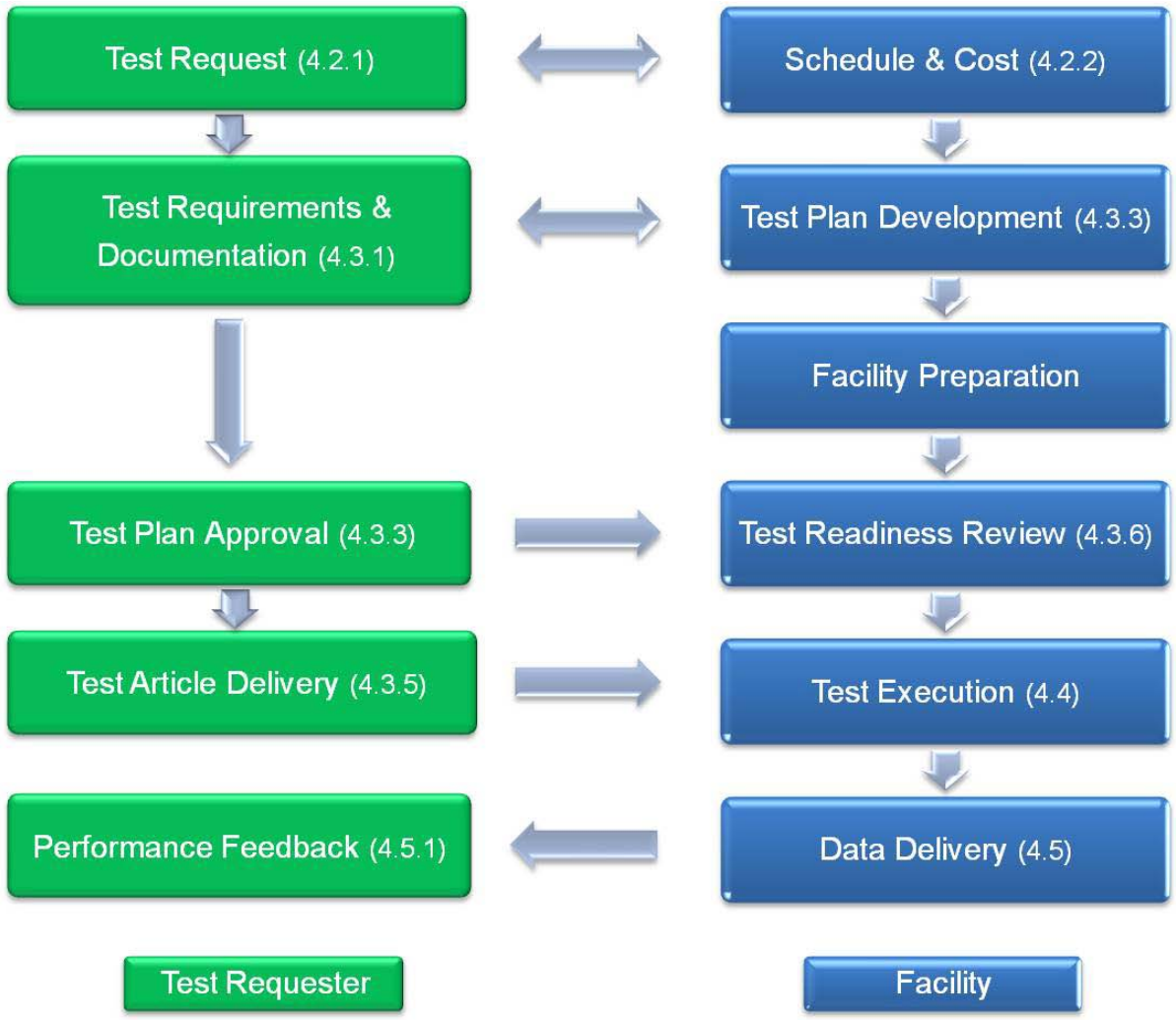
* See Appendix B for equipment that is available in the facility and Appendix C for sample test configurations.

3.0 Safety and Health

Safety is an integral part of the culture at NASA. Management, leadership, and employee involvement from all organizations are critical to the success of NASA's safety program. In order to ensure personal safety and a safe test environment throughout the process, the requester shall furnish the facility with the information necessary to perform a hazard assessment of the test article. Additionally, while visiting JSC, the requester shall follow all facility-specific safety and health requirements. A facility safety briefing shall be provided to all personnel prior to the start of the test. The safety briefing will include a review of the laboratory safety rules, potential hazards, and emergency procedures.

4.0 Test Process Flow

The flowchart presented below outlines the basic roadmap and significant milestones between the initial test request and delivery of test data. The flow is separated between Test Requester actions and Facility actions, highlighting interactions and inputs between the Test Requester and the Test Director.



4.1. Proprietary Information

The ADL provides for protection of proprietary information and hardware throughout the test process. The Test Requester shall clearly mark all export controlled or proprietary hardware items and data provided with a notice of restriction on disclosure or usage. The Test Director shall safeguard export controlled or proprietary items from unauthorized use and disclosure and ensure that test articles remain secure within the facility and are properly sequestered. Hardware items shall be returned to the Test Requester or disposed of in accordance with the Test Requester's instructions at the completion of the test activity.

4.2 Test Initiation Phase

The test initiation phase establishes the relationship between the Test Requester and the Test Director. The Test Requester shall provide a test request to the Test Director. The test request will be used to determine test feasibility and to develop an estimated cost and a preliminary test schedule. An initial requirements review meeting may be necessary in order to discuss the characteristics of the test article, the test approach, or any special considerations for the test. An onsite tour of the facility is highly recommended for familiarization and to provide an opportunity for an exchange of technical information.

Inputs:	Test Requester provides test request, identifies Test Article Expert
Activities:	Facility Test Director reviews test request to determine test feasibility
Outputs:	Facility delivers preliminary test plan, estimated cost and schedule to Test Requester

4.2.1 Test Request

The test request outlines the test requirements, test objectives, test article description, and preferred schedule. A Test Request Worksheet is provided in Appendix A. This worksheet addresses the basic requirements for testing in the ADL. It is suggested that the Test Requester complete this worksheet to facilitate the development of a preliminary test plan. At a minimum, the test request should include the following information:

Test Requirements and Objectives

A brief description of the test requirements, including, but not limited to, the following:

- Type of test
- Specific test conditions
- Proposed test approach
- Test parameters (duration, frequency, sound pressure level)
- Test data requirements

Test Article Description

A brief description of the test article, including, but not limited to, the following:

- Size/dimensions (provide drawings, sketches, photos)
- Weight
- Test article interface (structural, electrical, mechanical, other)
- Special considerations (hazards, cleanliness, compatibility)
- Handling, storage, and security requirements

Schedule

Identify the desired start date and the required date for delivery of the data/test report.

4.2.2 Schedule and Cost Estimate

A preliminary cost and schedule estimate, including major milestones, will be delivered following review of the Test Request Worksheet. Additional details and refinement of the cost and schedule estimate will be worked out with the Test Requester as test planning proceeds, with a final version to be agreed upon prior to the Test Readiness Review (TRR).

4.3 Test Preparation Phase

The detailed test plan and test schedule are finalized during the test preparation phase. The Test Requester shall provide detailed test requirements and test article documentation to the Test Director. A TRR will be held following approval of the test plan.

Inputs:	Test Requester provides test requirements and objectives, and test article documentation
Activities:	Facility and Test Requester develop test plan
	Facility begins assembly of facility-unique interface/support structure(s) (if needed)
	Test Requester ships/transports test article and associated support/peripheral equipment to JSC
Outputs:	Test Requester approves test plan, schedule, and final cost estimate
	Facility hosts TRR

4.3.1 Test Requirements

A complete understanding of test requirements and facility capabilities is mandatory for a successful test. Test requirements must be carefully defined and reviewed so that the test team understands the effect of the requirements on test facility preparation and test performance. The Test Requester shall provide a detailed list of test requirements, including, but not limited to, the following:

- Applicable audio system requirements/limits/specifications (e.g., customer specification, MIL-STD)
- Desired test conditions (frequency) and modes of operation
- Proposed test approach
- Test data requirements
- Test article interface
  - Orientation, load points, method of suspension or test article support
  - Electrical, mechanical, structural, other
- Data/instrumentation requirements (provided by Test Requester and laboratory)

4.3.2 Test Article Documentation

Test Article Drawings

The Test Requester shall provide detailed test article drawings as requested by the laboratory. Test article drawings are used to prepare the laboratory interfaces, test article support structures, and instrumentation connection points.

Material Safety Data Sheets

NASA must ensure that all materials exposed to test environments do not present a hazard to personnel or the laboratory. The Test Requester shall deliver to the facility Material Safety Data Sheets (MSDS) for materials used in the construction or operation of the test article and any associated support equipment. The Test Director will review the materials list for compatibility with the test environment.

Test Article Hazard Identification

The safety of facility personnel, facility equipment, and the test article is imperative to NASA. Potential hazards, material compatibility, and facility interfaces will be reviewed with the facility prior to testing. In certain instances, special precautions must be taken, due to the severity level of these potential hazards. The Test Requester may be asked to provide further information to clarify or mitigate a potential hazard. A Test Article Hazard Checklist is provided in Appendix A.

4.3.3 Test Plan

A test plan will be prepared through collaboration between the Test Director and the Test Requester. The final test plan shall be jointly approved by the Test Requester and the Test Director prior to the TRR. The test plan will be the controlling document, with respect to scope and approach for the test program. The test plan will include, at a minimum, the scope, test article description, test objectives, test requirements/limits, safety considerations, data requirements, and detailed test procedures. Changes to the test plan that occur after the TRR that result in a major change to the scope of the test or that present new hazards will require a delta TRR.

4.3.4 Test Schedule

A detailed schedule shall be developed jointly by the Test Director and the Test Requester. The schedule shall allow adequate time for creation, review, and approval of test plans, assembly of facility interfaces/structures, test article delivery, performance of the test, and creation of the test report. The schedule of other tests and maintenance activities will be reviewed for potential conflicts. Any identified conflicts shall be resolved prior to the TRR.

4.3.5 Test Article Delivery

The test article delivery date will be determined on a case-by-case basis. An agreed-upon delivery date shall be captured as a milestone in the test schedule. The Test Requester is expected to provide personnel to handle and set up hardware prior to the start of the test. The test article shall be secured within the test facility, unless directed to provide another means of storage. A physical inspection of the test article shall be performed by the Test Director and a functional test of the test article shall be performed by the Test Article Expert prior to the start of testing. Test Article Expert participation is mandatory throughout all test phases in order to provide immediate feedback on test article handling and any integration issues that arise.

4.3.6 Test Readiness Review

A TRR will be held to ensure the completion of all necessary facility and test article activities prior to test execution. The TRR will include the following:

- Review of the test plan, test procedures, and other required test documentation
- Confirmation of facility and test article readiness
- Review of configuration records, including facility interface control documents, pressure system certification, instrumentation calibration, and materials compatibility
- Assurance that controls are in place to mitigate risks or hazards identified in the Test Article Hazard Analysis

- Verification that data acquisition and processing functions are in place to adequately capture all critical data
- Confirmation that multimedia coverage is adequate to provide recognition and assessment of potential test anomalies

The TRR is chaired by the Test Readiness Review Board (TRRB) Chairman. Approval to proceed with test operations is granted by the TRRB. The Test Director shall ensure that all TRR actions have been accomplished prior to the start of the test. The TRR shall be conducted 1 to 5 business days prior to the start of the test. TRRB membership shall include the following:

NASA TRRB Chairman	Test Article Expert
Test Director	Safety Engineer
Test Safety Officer	Quality Engineer – if required by facility

4.4 Test Execution Phase

NASA encourages Test Requester participation in the testing activity. The Test Requester shall provide a Test Article Expert to verify that test setup and execution meet the stated requirements and objectives. The Test Article Expert also shall verify test article performance and approve requested test deviations during test operations.

Inputs:	Approval to begin testing received from TRRB
Activities:	Facility conducts testing activity
Outputs:	Test data package and/or detailed test report

4.4.1 Test Authority

The Test Director has the authority and responsibility to direct the test in accordance with the approved test plan and to terminate test activities per the test plan when danger is imminent or test control cannot be maintained. The Test Director will ensure that positive actions are taken to halt any steps in the test procedure whenever unsafe or hazardous test conditions arise. The Test Director, with the concurrence of the Test Requester, has the authority to terminate the test when sufficient data has been obtained to meet objectives or when it is determined that objectives cannot be met. Test team personnel will accept directions only from the Test Director or the Test Director's management.

4.4.2 Test Deviations

Changes to the test procedure shall be approved jointly by the Test Requester and the Test Director. Deviations that result in a major change to the scope of the test or that present new hazards shall require a delta TRR.

4.5 Test Closeout Phase

Either the data package or a detailed test report shall be delivered to the Test Requester within 15 business days following completion of testing. The Test Requester shall notify the Test Director upon receipt. Acceptance of the test data concludes the test activity.

Inputs:	Test completed
Activities:	Facility ships/transports test article to Test Requester
	Test Director delivers data package or detailed test report to Test Requester
Outputs:	Test Requester accepts data

4.5.1 Data Package

A data package is an assembly of test results. The format of the data package is normally specified by the Test Requester. The standard data package format includes a description of the test and objectives, test observations, test results, and data plots.

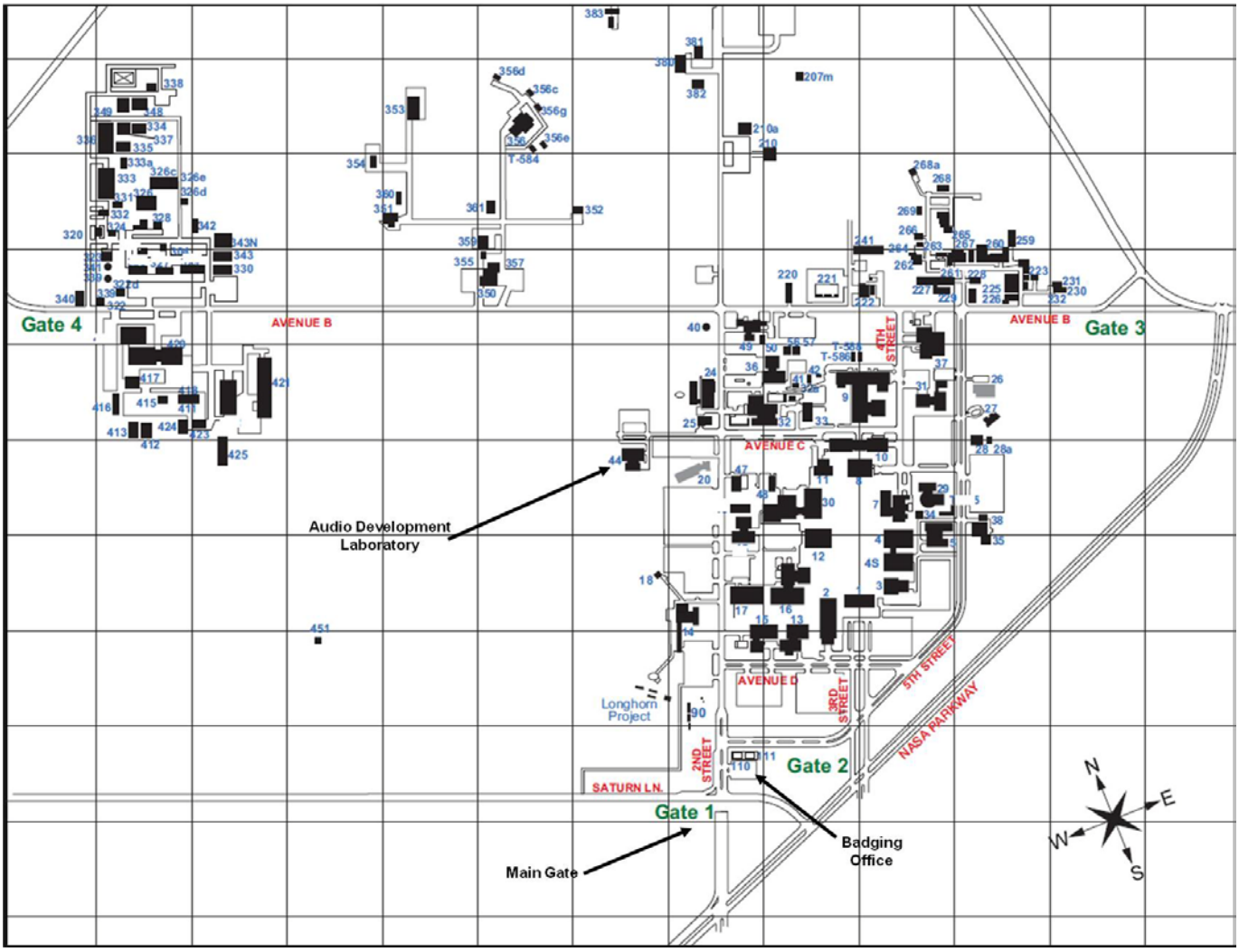
4.5.2 Customer Feedback

JSC encourages feedback from our customers. Evaluation of the services we provide enables continued improvement to our process. A Customer Feedback form is included in Appendix D. You are encouraged to complete this form and return it to the Laboratory Manager, following receipt of the test data. Your feedback is greatly appreciated.

5.0 Facility Access

Identification badges are required for all persons requiring access to JSC. The Test Director or designee will initiate a badge request for all Test Requester personnel who will be participating in the test activity. Badge requests must be submitted at least 4 days prior to the visit to prevent badge processing delays. Badge requests for non-U.S. citizens may require a minimum of 30 business days to process. Test Requester personnel shall arrive at JSC Building 110 to pick up temporary identification badges. Visitors to JSC must show a current picture identification (valid driver's license, U.S. passport, government ID card).

The ADL is located in JSC Building 44. A facility access briefing shall be provided to the Test Requester personnel requiring unescorted access to the facility prior to the start of the test. All other personnel requiring entry must be escorted by a person approved for access. Access to the facility is controlled through a cipher lock.



6.0 Roles and Responsibilities

Laboratory Manager – Responsible for operations of the facility. The Laboratory Manager is the initial point of contact for the Test Requester.

Test Director – Has overall responsibility for all phases of the test process.

Test Requester – The client requesting performance of a test activity. The Test Requester is responsible for the test article and for providing a Test Article Expert.

Test Article Expert – A representative of the Test Requester with thorough knowledge of the test article and how it is to be operated in the test environment. The Test Article Expert also is responsible for approving the test plan and verifying that test objectives are met.

Test Conductor – Assigned under the authority of the Test Director to execute the test in accordance with the approved test plan.

Test Safety Officer – Monitors and approves all hazardous operations for the test. The Test Safety Officer has the authority to recommend the discontinuance of test operations considered unsafe.

Safety Engineer – Reviews the Test Article Hazard Checklist and generates the integrated hazard analysis for the test facility to identify any additional hazards that could result in injury to personnel.

Facility Quality Engineer – Responsible for verifying that the test facility is ready for the test by ensuring that all constraints to the test have been closed.

Responsibilities Matrix

Item	Test Requester	Facility
Test Request Worksheet	Create	Review and provide assistance as needed
Cost and schedule	Provide joint creation/approval	Provide joint creation/approval
Hazards	Identify test article hazards	Create test article/facility integrated hazard analysis
Test plan	Provide joint creation/approval	Provide joint creation/approval
Test Readiness Review	Provide joint approval	Conduct review and provide joint approval
Test execution	Verify test article performance Verify that test setup and execution meet objectives Approve requested deviations	Execute test
Test data/results	Notify Test Director of data package or detailed test report receipt and acceptance	Deliver to Test Requester
Shipping	Provide instruction	Execute per request

Acronyms

°C	Degrees Celsius
°F	Degrees Fahrenheit
AC	Alternating Current
ADL	Audio Development Laboratory
dB	Decibel(s)
dBA	Decibel A-weighted
DC	Direct Current
e.g.	For Example
ESD	Electrostatic Discharge
ESTL	Electronic Systems Test Laboratory
ft	Feet
H	Height
HATS	Head and Torso Simulator
Hz	Hertz
IR	Infrared
JSC	Johnson Space Center
kHz	Kilohertz
L	Length
lb	Pound(s)
MIL-STD	Military Standard
MSDS	Material Safety Data Sheets
NASA	National Aeronautics and Space Administration
Ops	Operations
PESQ	Perceptual Evaluation Speech Quality
RF	Radio Frequency
RTA	Real-Time Audio Analyzer
SPL	Sound Pressure Level
TRR	Test Readiness Review
TRRB	Test Readiness Review Board
UV	Ultraviolet
W	Width

Appendices

A. Test Request Worksheet

B. Facility Equipment

C. Sample Test Configurations

D. Customer Feedback

Appendix A Test Request Worksheet

Test Requester Information

Test Article Expert:	Contact Information (Phone, E-mail, Address):

Test Objectives

Purpose of Test:	
Proposed Start Date:	Critical Start Date:

Test Article

Test Article Description:	
Physical Dimensions (L/W/H):	
Weight:	Setup Time:
Support/Ancillary Equipment Provided by Requester:	

Test Article Handling Requirements

Cleanliness Level:	Controlled Access:
Electrostatic Discharge (ESD) Requirements:	
Special Moving/Handling:	

Power Requirements

Input Voltage Type (AC, DC, Both):	Input Voltage Requirement (Volts):	
Input Power (Watts or Amps):	Number of Power Connections:	Power Phase:

Test Environment

Complete the Test Environment table below or include your desired acoustic profile as an attachment.

1/1 Octave Band (Hz)										
Sound Pressure Level	31.5	63	125	250	500	1000	2000	4000	8000	16,000

Weighting			
A	B	C	None
☐	☐	☐	☐

1/3 Octave Band (Hz)										
Sound Pressure Level	31.5	40	50	63	80	100	125	160	200	250
	315	400	500	630	800	1k	1.25k	1.6k	2k	2.5k
	3.15k	4k	5k	6.3k	8k	10k	12.5k	16k		

Weighting			
A	B	C	None
☐	☐	☐	☐

Test Requirements

Test Article Interface (e.g., support structure, connectors):
Specification(s) to be met:

Instrumentation

Instrumentation Provided by Test Requester:
List the primary measurements to be made (e.g., frequency, sound pressure level, sound transmission loss):

Data Acquisition and Recording

Number of Channels:	Audio/Video Recording (Yes/No):
Sampling Rates:	Photographic Film (Yes/No):
Real-Time Data Processing (Yes/No):	High Speed/Low Speed:

Test Article Hazard Checklist

A hazard analysis statement is required for any of the following applicable attributes of any of your provided hardware (e.g., test article, support equipment).

Hazard	Y	N	Comments
Mechanical	☐	☐	
Handling (> 40 lb or > 4 ft, any dimension)	☐	☐	
Instability	☐	☐	
Sharp Edges	☐	☐	
Pinch Points	☐	☐	
Exposed Mechanisms (e.g., rotating, reciprocating)	☐	☐	
Pressure Systems	☐	☐	
Stored Energy (e.g., springs, weights, flywheels)	☐	☐	
Ejected Parts, Projectiles	☐	☐	
Electrical	☐	☐	
Voltage (> 50 volts)	☐	☐	
Batteries	☐	☐	
Generation/Storage (e.g., coils, magnets, capacitors)	☐	☐	
Electrostatic Sensitive Devices	☐	☐	
Thermal	☐	☐	
Hot Surfaces (> 113 °F, 45 °C)	☐	☐	
Heaters	☐	☐	
Cold Surfaces (< 39 °F, 4 °C)	☐	☐	
Cooling Devices	☐	☐	

Hazard	Y	N	Comments
Radiation	☐	☐	
Ionizing	☐	☐	
Non-Ionizing	☐	☐	
Laser	☐	☐	
Microwave	☐	☐	
Infrared (IR)	☐	☐	
Ultraviolet (UV)	☐	☐	
Radio Frequency (RF)	☐	☐	
Visible Light, High Intensity	☐	☐	
Material	☐	☐	
Uncontained Brittle Materials	☐	☐	
Test Environment Incompatibility	☐	☐	
Contained Fluids	☐	☐	
Toxic, Corrosive, Flammable Fluids	☐	☐	
Biohazards	☐	☐	
Miscellaneous	☐	☐	
Noise Level (> 85 dBA)	☐	☐	
Ultrasonic	☐	☐	

Appendix B Facility Equipment

Equipment and Capabilities
• Bruel and Kjaer Pulse Audio Analyzer – Real-time Audio Analyzer (RTA) for 1/N octave spectral analysis • SoundCheck Audio Test System – Manual and automated electro-acoustic measurement – Total harmonic distortion, signal-to-noise, sensitivity, and frequency response • Precision Measuring Microphones • Audio Filters, Equalizers, and Crossovers • White/Pink Noise Generators • 48-Track Audio Recording Capability • Head and Torso Simulator (HATS) • Audio Calibration Equipment • Connectivity for Integrated Testing With the Electronic Systems Test Laboratory (ESTL) Facility • Calibrated Portable Sound Level Meter • Audio Dosimeters • Perceptual Evaluation Speech Quality (PESQ) Speech Quality Analyzer

Appendix C Sample Test Configurations

Shuttle Crew Escape Communications
Hearing Protection Test

Speech Intelligibility Testing

Appendix D Customer Feedback

Test Article: _____

Type of Test: ☐Certification ☐Evaluation

Test Date: _____

Your evaluation of our service product will enable us to serve you better.

Evaluator Name:	Organization/Mail Code:	Phone:

Please select a number between 0 and 100 to rate our performance.

Test Planning/Reporting Phase:

Ease of test coordination: _____

Satisfaction with test dates: _____

Timely completion of test plan: _____

Timely completion and scheduling of TRR: _____

Timely test reporting: _____

Technical adequacy of test report: _____

Laboratory Operations:

Completion of test objectives: _____

Competence of test personnel: _____

Satisfaction with time utilization: _____

Test data availability at test completion: _____

Explanation of rework required (if applicable): _____

Signature:	Date:

(For Laboratory Use Only)	Planning/Reporting:
Average of Evaluator's Scoring:	Laboratory Ops:

Return responses to: EV3/Andy Romero
NASA Johnson Space Center
Houston, TX 77058
Phone: 281-483-0159