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# Introduction

The MPEG-I suite of standards, “Coded Representation of Immersive Media,” is intended to support emerging virtual and augmented reality applications. This Call for Proposals (CfP) is for technology to be standardized in Part 4, “Immersive Audio.” Along with other parts, Part 3, “Immersive Video” and Part 2, “Systems Support,” the suite of standards will support a Virtual Reality (VR) or an Augmented Reality (AR) presentation in which the user can navigate and interact with the environment using 6 degrees of freedom (6 DoF), that being spatial navigation (x, y, z) and user head orientation (yaw, pitch, roll).

The goal in MPEG-I presentations is to impart the feeling that the user is actually present in the virtual world. Audio in the world (or scene) is perceived as in the real world, with sounds coming from an associated visual figure. That is, perceived with the correct location and distance. Physical movement of the user in the real world is perceived as having matching movement in the virtual world. Furthermore, and importantly, the user can interact with the virtual scene and cause sounds that are perceived as realistic and matching the user’s experience in the real world.

The architecture for Part 4, Immersive Audio is shown in Figure 1 of “MPEG-I Immersive Audio Architecture and Requirements” [1]. A key stipulation of the architecture is that the audio compression engine used in MPEG-I Immersive Audio is MPEG-H 3D Audio (ISO/IEC 23008-3), specifically LC Profile. This is shown in the tan shaded box of Figure 1 in [1]. The other audio decoder, “Low-Delay Decoder”, is out of scope for MPEG-I Immersive Audio, and is shown in the purple shaded box of Figure 1 in [1]. The new technology that is to be standardized in MPEG-I Immersive Audio is shown in the green shaded boxes of Figure 1 in [1], and primarily consists of:

* Technology for rendering the audio presentation while permitting the user to have 6 DoF movement.
* Metadata to support this rendering.
* A bitstream syntax that enables storage and streaming of the MPEG-I Immersive Audio content. Since the coding of all audio signals is done using MPEG-H 3D Audio LC Profile, the MPEG-I bitstream must be able to convey an MPEG-H 3D Audio LC Profile bitstream.

The framework for evaluating the CfP submitted technology is shown in Figure 1 of [4]. This figure shows that the audio media signals are encoded and decoded off-line and then made available to all proponents. This coding is done using MPEG-H 3D Audio LC Profile, and in this way audio signal compression is “out of scope” when responding to this CfP.

Furthermore, an important component of the evaluation of proponent technology is assessing subjective quality of the MPEG-I Immersive Audio presentation, which is done via subjective listening tests in which all proponent MPEG-I Immersive Audio rendering technology must run in real-time on the MPEG-I Audio Evaluation Platform (described in [4]).

Additional components of the evaluation of proponent technology will be done via proponent-supplied description of the functionality of the submitted technology and also via proponent objective measurements of aspects of the technology (e.g. motion-to-sound latency), which must be included in the submitted proponent documentation.

# Definitions

The definitions for terms associated with this Call for Proposals are found in [1].

# CfP documents

The CfP package consists of the following documents:

N028 MPEG-I Immersive Audio Architecture and Requirements

N054 MPEG-I Immersive Audio Encoder Input Format

N055 MPEG-I Immersive Audio Augmented Reality Listener Space Description Format

N056 MPEG-I Immersive Audio Call for Proposals

At the 4th WG 6 Meeting, July 2021, the following CfP documents will issue:

Nxxx MPEG-I Immersive Audio Documentation for the Audio Evaluation Platform

Nxxx MPEG-I Immersive Audio MPEG-I Immersive Audio CfP Supplemental Information and Clarifications

Nxxx MPEG-I Immersive Audio Test and Evaluation Procedures

Nxxx MPEG-I Immersive Audio Core Experiment Methodology

At the 5th WG 6 Meeting, October 2021, the following CfP documents will issue:

Nxxx MPEG-I Immersive Audio Subjective Test Logistics

# Submission Process

## CfP Time Line table

Each entry in the table is described in a section below. WG 6 is the SC 29 working group WG 6 MPEG Audio Coding. This timeline may be altered by agreement of WG 6 experts.

|  |  |  |  |
| --- | --- | --- | --- |
| **Meeting** | **Date** | **Who** | **Action** |
| 3 | Apr 2021 | WG 6 | Issue Call for Proposals documents |
| 4 | Jul 2021 | WG 6 | Issue additional documents supporting CfP |
|  |  | WG 6 | Prepare Test Material |
|  | 2021-09-27 | Proponent | Register |
|  |  | Proponent | Get Audio Evaluation Platform  Get test material |
| 5 | Oct 2021 | WG 6 | Issue additional documents supporting CfP |
|  | 2021-11-01 | Test Administrator | Distribute TestConfigFiles, ListenerFiles to Test Labs |
|  | 2021-11-01 | Proponent | Optional, preliminary submission of real-time Max External and bitstream files. |
|  | 2021-11-03 | Test Administrator | Begin Debug of preliminary proponent real-time Max Externals |
|  | 2021-11-10 | Proponent | Final submission of real-time Max External and bitstream files, and other required documentation. (e.g. latency, loudness) |
|  | 2021-11-15 | Test Lab | Begin subjective tests.  Begin complexity evaluation. |
|  | 2021-12-13 | Test Lab | Submit subjective test data |
|  |  | Test Administrator | Perform analysis of subjective test data and submit result as contribution to 6th WG 6 meeting |
|  | Upload deadline for 6th WG 6 meeting | Test Lab | Submit complexity data |
|  | Upload deadline for 6th WG 6 meeting | Proponent | Submit proponent documentation as contribution to 6th WG 6 meeting |
| 6 | Jan 2022 | WG 6 | Evaluate Call for Proposals submissions and select technology |
|  | 2 weeks after close of 6th WG 6 meeting | Proponent | Make source code for Test 1 winner available to WG 6 experts. |
| 7 | Apr 2022 | Proponent | Submits Working Draft (WD) and Reference Model source code (RM) for selected technology as input contributions to the WG 6 meeting. |

Table 1 – CfP Time Line

## Envisioned Timeline for the MPEG-I Immersive Audio Standard

It is envisioned that the timetable for progress of the MPEG-I Immersive Audio standard will be as follows:

|  |  |  |
| --- | --- | --- |
| **WG 6 Mtg** | **Date** | **Action** |
| 3 | Apr 2021 | CfP |
| 4 | Jul 2021 | Test and Evaluation Document |
| 5 | Oct 2021 | Test Logistics Document |
| 6 | Jan 2022 | Evaluation |
| 7 | Apr 2022 | WD |
| 8 | Jul 2022 |  |
| 9 | Oct 2022 |  |
| 10 | Jan 2023 | CD |
| 11 | Apr 2023 | DIS |
| 12 | Jul 2023 | Verification Test |
| 13 | Oct 2023 | FDIS |

Table 2 - Standardization Time Line

## Prepare Test Material

WG 6 experts will encode and decode all audio signals that are components of all test scenes and create a complete package for each scene that is according to [2]. Signal encoding and decoding will be at a bit rate per audio object, channel set or HOA signal as indicated in the tables in [6], Annex A, using MPEG-H 3D Audio LC profile. The Test Administrator, supported by WG 6 experts, shall put encoded/decoded test items in appropriate folder location of the AEP, as indicated in the AEP documentation [4].

## Register

Proponent must register on or before the date shown in the CfP Time Line table above, an intention to participate in the CfP. Registering an intent is not binding and registered parties are not required to submit proposals. However, parties that do not register will not be able to submit proposals. Register by sending an email to Schuyler Quackenbush (Convenor, WG 6 MPEG Audio Coding, srq@audioresearchlabs.com). Email should indicate

* Company name
* Contact name and contact email address
* The envisioned scope of the proposal (e.g. will it process all or only some content types, will it be valid for all or only some subjective tests, will it meet all or only some requirements). This envisioned scope is not binding and is not a restriction on proponent response, but is rather for planning purposes only.

After registration, the proponent will receive two “ProponentIDs” (<Proponent\_ID>) for use in submission of Max External and other materials (e.g. bitstream files). This permits each proponent to have two submissions, e.g. each tuned to a different operating point.

## Get Test Material

Proponent should get the test material on the date shown in the CfP Time Line table, above. Test material is available by downloading the AEP master branch, indicated in [4]. The test items used in the evaluation process shall be made available in the format defined in [2]. The list of test material is shown in Annex A. Test material that requires execution of a use agreement is indicated, along with contact person for obtaining the agreement and information on how to access the test material.

## Get Audio Evaluation Platform

The MPEG-I Immersive Audio CfP Audio Evaluation Platform (AEP) is needed to perform the CfP subjective tests, and a description of the AEP can be found in [4]. Proponents and organizations wishing to participate in the CfP subjective tests will need to obtain the AEP.

Proponents are encouraged to obtain the AEP to verify that the Max External for their submission can run in real time within the constraints of the AEP.

## Mandatory Equipment, Software and Data Components

The use of the following equipment, software and data components is mandatory in the CfP:

* The Beyerdynamic DT-990 Pro headphones in the CfP tests.
* Specific computer hardware to run the Audio Evaluation Platform (AEP) on. See [4] for details.
* Specific software to run the AEP. See [4] for details.
* The use of the HR filter set ‘FABIAN with diffuse field equalization’ without headphone equalization by all renderers. The filter set is available as part of the AEP platform.

## Measure Submission Latency and Loudness

In order for the test administrator to create appropriate test configuration files, proponent should determine the signal latency of each of its Max External plugins according to the signal latency definition provided in [6].

Furthermore, loudness data for each of the Max External plugins for all scenes must be provided. Proponent shall use the loudness measurement functionality of the AEP, as described in [4].

## Submit Real-Time Max External, Bitstreams, Latency and Loudness

**Preliminary Submission**

Proponents may optionally submit Max Externals and bitstream files on date shown in the CfP Time Line table, above. The Test administrator will run the proponent Max Externals in the AEP and report any issues, e.g. real-time fault reports or other errors that might prevent a successful evaluation in the subjective tests.

**Final Submission**

Proponent must submit final Max Externals and other proposal materials no later than the date shown in the CfP Time Line table, above. Submission is via FTP with a site URL and username/password communicated by the Test Administrator to all registered proponents.

Two randomly assigned proponent IDs will be delivered to each proponent by the Test Administrator, sufficient to permit two proponent submissions. These IDs must not be disclosed, as they are visible to all Test Labs and Test Labs should not be able to determine the source of the submissions (i.e. name of proponent).

Proponents will submit a bitstream (i.e. MPEG-I metadata) file for each of the test material items in each of the subjective tests for each of the proponent submissions. Bitstream (i.e. MPEG-I metadata) files shall enable random access in time on 1 second time intervals. This is additionally discussed in Table B-1, in [6], and Requirement 8 of [1]. The size of these bitstreams (or metadata files) is not constrained, however a lower bitrate (i.e. file size) is preferred according to Requirement 2 of [1] as described in [6].

For each submission, proponents must provide:

* A real-time Max External that performs the proposed technology
* Bitstream (i.e. MPEG-I Immersive Audio metadata) files for each of the test material items in each of the subjective tests
* Signal latency of the Max External (for each configuration used in each of the tests)
* Loudness output of the Max External as specified in AEP [4] for each of the test material items in each of the tests.

Manual tuning (i.e. per-item tuning) of the encoder used in the process of preparation of submitted material is explicitly prohibited.

The Max External shall be named as:

ME\_<Proponent\_ID>~.mxe64 (windows platforms only)

The Bitstreams shall be named as:

<Scene\_ID>\_Test<Test\_Number>\_<Proponent\_ID>.bin (or whatever extension the proponent wishes)

Where

Test\_Number is 1, 2 or 3

Scene\_ID\_ is the AudioScene’s id attribute from the scenes EIF.

The Max Externals submitted by proponents would be called from two threads: a real-time DSP thread and a message thread. The latter would process OSC messages from Unity. Proponents must configure their submissions to minimize the time spent in the message thread. For example, there should be no calculations done within the message thread. Proponents are advised to inspect “Max External Renderer Skeleton” code documented in [4] and the MPEG GitLab repository.

Test Administrator, supported by WG 6 experts, shall put proponent Max Externals and bitstreams in appropriate folder locations of the MPEG GitLab repository, as indicated in the AEP documentation [4].

## Conduct Subjective Tests

Get test code, test items and associated metadata, which is available by downloading the AEP branch to be communicated by Test Administrator. Any WG 6 member organization with the appropriate listening environment, laboratory equipment and expertise can participate in the subjective tests. Subjective testing will be conducted as set forth in [6], which gives details on test methodology and the requirements for HMD/Headphone listening. Logistics for conducting the subjective tests are set forth in [7]. Since submissions are anonymized via Proponent ID, proponents are welcome to participate.

### Test 1 -- Virtual Reality

This test will form the “core” technology for RM0.

|  |  |
| --- | --- |
| **Test 1** |  |
| Presentation | HMD (HTC Vive or Vive Pro) with headphones. |
| Material | Objects, Channels and 3DoF HOA (i.e. “interior” HOA, in which user position does not influence rendering)  Material for Test 1 is listed in Table A-1 of Annex A, found in [6]. |
| Evaluation | Subject uses 6DoF full body motion in assessment. |

### Test 2 -- Augmented Reality

Technology selected in this test will be merged into the Test 1 “core” technology.

|  |  |
| --- | --- |
| **Test 2** |  |
| Presentation | HMD (Microsoft Hololens or Hololens 2 (preferred)) with headphones. |
| Material | Objects, Channels  Material for Test 2 is listed in Table A-2 of Annex A, found in [6]. |
| Evaluation | Subject uses 6DoF full body motion in assessment. |

### Test 3 -- Virtual Reality with 6DoF HOA signals

Technology selected in this test will be merged into the Test 1 “core” technology.

|  |  |
| --- | --- |
| Test 3 |  |
| Presentation | HMD (HTC Vive or Vive Pro) with headphones. |
| Material | 6DoF HOA, in which user position influences rendering, including:   * “interior/exterior” HOA, and * “multi-point” HOA, in which there are HOA signals located at more than one position,   and Objects, Channels  Material for Test T3 is listed in Table A-3 of Annex A, found in [6]. |
| Evaluation | Subject uses 6DoF full body motion in assessment. |

Tests 1, 2 and 3 are intended to assess subjective perception of all aspects of the VR/AR experience, including those listed in Table 3, below.

|  |
| --- |
| **Characteristic** |
| Audio timbral quality |
| Audio distortions and artefacts |
| Audio source localization quality |
| Audio source spatial extent quality |
| Audio source directivity quality |
| Audio reverberation, occlusion and diffraction quality |
| Consistency of audio with respect to user motion (i.e. sufficiency low motion to sound latency) |
| Consistency of audio with respect to visual cues (i.e. co-localization of visual and auditory sound objects) |
| Overall auditory immersion elicited by presented scene |
| Plausibility of overall experience |

Table 3 – Non-exhaustive List of Perceptual Characteristics to be Tested

## Conduct Objective Evaluations

Proponents must provide the objective measurement of the following parameters. Details on how to measure are given in [6], Annex B.

* computational complexity,
* latency (motion to sound latency as well as signal latency),
* bitrate,
* memory usage.

In addition, proponents must provide objective or descriptive characterizations of their proposals as detailed in Table B-1 of Annex B.

* ***Other objective measurements or written descriptions***

A template for the submission of this information is given in Annex B. The proponent must submit documentation that contain a numerical measurement of the objective criterion listed in this section, along with a description of how the measurement was made, including all assumptions made for the measurement setup.

In addition, the proponent must show the extent that their submission fulfills the requirements listed in [1]. A template for the submission of this information is also given in Annex B.

## Submit Subjective Test Data

All labs participating in the subjective tests will submit test data to the Test Administrator in a format according to “MPEG-I Immersive Audio Subjective Test Logistics” [7] no later than the date indicated in the CfP Time Line table, above. This will allow an analysis of test results to be submitted as a WG 6 meeting contribution.

## Perform Analysis of Subjective Test Data

The Test Administrator will collect subjective test data and perform an analysis. Data analysis and computation of a Figure of Merit will be done as indicated in [6]. It is envisioned that both Mean and 95% Confidence Interval will be performed. There will be a process to assess the suitability of merging data from the several Test Labs.

## Submit Proponent Documentation

Proponents submit as a contribution to the MPEG meeting indicated in the CfP Time Line table, above:

* A written description of the technology having sufficient detail to permit technical discussions.
* Objective test results, as indicated in Annex B
* Description of how requirements are met (for the methodology “Description”, See Annex B). Also, Documentation that permit Audio subgroup to check objective test results.
* Evidence of the performance of the technology, as described in [6]

Proponents that are WG 6 members shall register these documents as contributions to the WG 6 meeting and send title and author information to Schuyler Quackenbush, Convenor of WG 6, prior to the close of contribution upload deadline. All proponents are urged to become WG 6 members. However, proponents that are not WG 6 members shall email the documents to Convenor of WG 6 two weeks prior to the WG 6 meeting at which proponent documentation materials are due, so that he can register and upload them as contributions. The documents should be written in Microsoft Word. The Convenor of WG 6 will extend an invitation to the WG 6 meeting so that a non-member proponent can present their contributions and participate in the selection process.

The results of the subjective tests also will be available as a contribution to this WG 6 meeting.

## Evaluate CfP Submissions and Select Technology

At the WG 6 meeting indicated in the CfP Time Line table, above, submissions will be evaluated by the WG 6 audio experts. It is strongly urged that proponents have experts familiar with the proposed technology attend in order to allow discussions on details of the proposals. It is envisioned that at least one submission will be selected as technology for the Working Draft of MPEG-I Immersive Audio.

Submissions shall be evaluated, considering all submitted information including subjective listening test results.

Proposals do not have to fulfill all requirements. However, proposals that fulfill more requirements will be considered more favorably. Requirements that are not fulfilled by the selected technology will be addressed in the Core Experiment (CE) process, which may include CEs using other submitted technologies in order to address all requirements.

The main Test 1 winner shall within 2 weeks of the close of the WG 6 meeting where the selection occurs, make available to WG 6 the source code used to compile the winning Max External.

If it is the assessment of the WG 6 audio experts that there is no single best proposal, then the WG 6 will draft a workplan on how to merge the best-performing technologies into a single unified technology.

## Submit WD Specification and RM Source Code

At the WG 6 meeting indicated in the timetable above, the winning proponent shall submit as contributions a Working Draft (WD) of the specification and Reference Model (RM) source code for the selected technology. The WD must include a normative specification of the MPEG-I Immersive Audio metadata decoding and audio rendering process. The RM must include code that performs the MPEG-I Immersive Audio metadata decoding and audio rendering process.

In addition, the WD must include an exemplary description of how the MPEG-I metadata is extracted and encoded based on the scene description and audio signals (i.e. the MPEG-I Immersive Audio “encoder” algorithms). Such encoders extract information important for acoustic modelling from EIF data and provide an efficient representation and encoding. Metadata might be modified and amended (based on justifiable assumptions) to enable lossy compression, optimization, representation conversion, etc.

To match the WD, the RM must include source code that implements the described extraction algorithms. In other words, source code for an MPEG-I Audio encoder that reads the Encoder Input Format (EIF) scene data and audio signals and produces an MPEG-I Audio compressed metadata file. Note that this need not be the exact algorithm used in the proponent’s submission to the CfP. *However, subsequent Core Experiment work for the collaborative development of the MPEG-I Immersive Audio technology shall use the proponent-submitted MPEG-I Immersive Audio “encoder” algorithm and corresponding submitted source code as the “baseline” system in CE performance comparisons, against which CE technology is evaluated.*

The RM0 source code used as a starting point for Core Experiments may differ from the source code used to create the “winning proposal” Max External. This may be due to “code cleanup” or the merging of code from low complexity / low bitrate category winners. The MPEG-I Immersive Audio Test and Evaluation Procedures [6] describes a process that shall be used to verify the performance of the system built from the submitted RM source code with respect to the performance of the “winning proposals” evaluated in the CfP.

# Core Experiments

Subsequent to selecting technology and creating a first Working Draft (WD), a collaborative development of the work will occur, using the methods documented in [8].

If the technology selected from the CfP does not address all requirements, or to the extent that the CfP does not permit evaluation and selection of technology that addresses all requirements, then technology that addresses the remaining requirements shall be incorporated via the Core Experiment process. It is expected that this will include:

* **Presentation Modes**, specifically via loudspeakers (requirements 21, 22, 23)
* **Interoperability between 3DoF and 6DoF platforms** (requirements 25, 26 and 27)
* **Spatial interpolation of HRTF to support the use of spatially sparse HRTFs** (requirements 15, 18)
* **External rendering interfaces** (requirement 17)
* **Subscenes** (requirement 4)

Changes to the EIF [2], LSDF [3] and AEP [4] will be considered in the CE phase if proponent(s) demonstrate that the proposed changes increase system performance and/or system flexibility.

Other candidate technologies for CEs, e.g. technologies that permit the final MPEG-I Immersive Audio specification to fulfill all requirements in [1], might be those that support the following:

* Social VR
* Local metadata interface (e.g. local acoustics for AR)
* Interoperability (i.e. with MPEG-H 3D Audio for user with 0DoF and 3DoF)
* Earcons

Finally, it is acknowledged that new CEs may require new test scenes that are able to best support the specific use case or requirement addressed by the CE.

# Verification Tests

The performance of the new technology shall be measured via a formal subjective test, to be carried out after the Committee Draft stage of the standardization process. An acceptable level of performance, as judged by the consensus of the MPEG Audio subgroup, must be achieved in order for the technology to progress in the standardization process.

It is envisioned that the Verification Test will use a platform similar to the AEP [4], that is using an HMD and employ user full body motion, so that it is an as realistic as possible assessment of the MPEG technology as would be used in target applications.

# Test Administrator

For any questions related to this Call for Proposals or associated evaluation procedures please contact the Test Administrator:

Dr. Schuyler Quackenbush, Convenor, WG 6 MPEG Audio Coding

Audio Research Labs

336 Park Ave, Suite 200

Scotch Plains, NJ 07076

Phone: +1 908 490 0700

email: srq@audioresearchlabs.com

# References

Note: Documents without numbers are to be issued at a future WG 6 meeting.

1. N028 MPEG-I Immersive Audio Architecture and Requirements
2. N054 MPEG-I Immersive Audio Encoder Input Format
3. N055, MPEG-I Immersive Audio Augmented Reality Listener Space Description Format
4. Nxxx MPEG-I Immersive Audio Documentation for the Audio Evaluation Platform
5. N056 MPEG-I Immersive Audio Call for Proposals (*this document*)
6. Nxxx MPEG-I Immersive Audio Test and Evaluation Procedures
7. Nxxx MPEG-I Immersive Audio Subjective Test Logistics
8. Nxxx MPEG-I Immersive Audio Core Experiment Methodology

# Copyright Header for MPEG-I Immersive Audio Reference Software

All MPEG-I Immersive Audio Reference Software files shall contain the following header:

##########################################################################

This software module was originally developed by

<CN>

in the course of development of ISO/IEC 23090-4 for reference purposes and

its performance may not have been optimized. This software module is an

implementation of one or more tools as specified by the ISO/IEC 23090-4

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