



Defining 3D Home Master: Summary Report of SMPTE Task Force on 3D to the Home

By William Zou, Chair, SMPTE Task Force on 3D to the Home

In August 2008, the Society of Motion Picture and Television Engineers (SMPTE) established a task force to define the parameters of a stereoscopic 3D mastering standard for content viewed in the home. The project, called 3D to the Home, was the first step in propelling the 3D home entertainment industry forward by setting the stage for a standard that will enable 3D feature films and other programming to be played on fixed devices in the home, regardless of the delivery channel. With cross-industry participation and contribution, the task force defined the concept of a 3D Home Master, identified use cases from the perspective of various entities in the supply chain of the 3D content to the home, and developed requirements for the 3D Home Master. In March 2009, the task force completed its assignments and published its report, which will form the basis for developing actual format standards within SMPTE. This report has been distributed to other standards development organizations in support of their development of related distribution and presentation standards.

The effort was initiated on August 19, 2008. The inaugural meeting was hosted by the Entertainment Technology Center (ETC) at the University of Southern California (USC) and some 160 professionals from all parts of the industry were in attendance. 3D technology vendors were also invited to present their solutions and demonstrated latest implementation. With a six-month schedule to complete the assignments, the task force developed an effective plan to form three drafting teams to address specific areas: Issues and Challenges, Minimum Requirements, and Evaluation Criteria. Monthly face-to-face meetings were held to define the direction, and weekly conference calls were held to develop drafts. During the course, more than 200 people from 13 countries and representing movie studios, broadcasters, cable, and direct-to-home (DTH) service providers, as well as consumer electronics manufacturers and semiconductor companies, contributed to and participated in the task force.

At the initiation of the effort, the task force was chartered with defining “what standards would be needed to establish rapid adoption of stereoscopic A/V content from content mastering to consumption in the home via multiple types of distribution channels (e.g., packaged, broadcast, satellite, cable, Internet) with consideration for downward scalability (e.g. portable/mobile).” The charter was broad and potentially included standards for content mastering and distribution formats, common interfaces for 3D display, performance requirements related to human factors, and backward compatibility related to distribution infrastructure and legacy devices.

During the initial phase of this effort, the task force redefined the scope and goals to be more sharply focused, and to specifically address the standards needed for the 3D Home Master that would be distributed after post-production to the ingest points of the distribution channels (e.g., Blu-ray Disc or DVD authoring facility, or an ingest center of a broadcast operator). The 3D content will be rendered on different types of 3D displays. It is important to note that neither the 3D Home Master, nor the format used to store/represent 3D content in the Master is meant for distribution to the home. The ingest point in each type of distribution network is expected to convert the content in the 3D Home Master into the appropriate format needed by the distribution system.

The 3D Home Master was defined in the document to be an “uncompressed and unencrypted image format or file package derived from a 3D Source Master. The 3D Home Master is intended to be used in the creation of 3D Distribution Data.” The primary objective of the task force was to generate requirements for the 3D Home Master, which would drive specifications for the 3D Home Master in a subsequent phase of SMPTE standardization activity.

The task force first identified various use cases from the perspective of various entities in the supply chain of the 3D content to the home, and those use cases that had an impact on the format of the master were used to generate requirements. In generating use cases, priority was given to distribution via physical media, broadcast channels, and online mechanisms. Consumer viewing of the content on TV-type devices was also given a higher priority than viewing on mobile devices such as mobile phones and in-car devices. However, the task force did consider use cases and requirements that included downward scalability (e.g., portable/mobile).

SUMMARY OF TASK FORCE REPORT

The key accomplishment of the task force is the development of a comprehensive report. It has the following sections:

- Section 1 is the introduction.
- Section 2 presents a definition of terms and concepts that are used in this report.



- Section 3 presents a high-level description of the end-to-end supply chain of the 3D content and defines the scope of the task force's consideration in view of this high-level view of the chain.
- Section 4 lists use cases considered by the task force, and also whether and to what extent each use case impacts the specification of the 3D Home Master.
- Section 5 lists the requirements for the 3D Home Master as identified by the task force for consideration in a subsequent standardization effort by SMPTE to generate technical specifications for the master.
- Section 6 provides additional context to the completed effort of the task force and lists specific areas that were not considered due to the nascent aspect of the field. Caveats and areas for further study are indicated.
- Section 7 contains recommendations on standardization activity that SMPTE needs to pursue to support commercially successful deployment of 3D content to the home.
- The report includes an appendix that cross-references the use cases to the requirements generated by the task force. This is meant to provide the subsequent standards generation activities in detailed context for the requirements.

OUTLINE OF THE KEY COMPONENTS

3D Glossary

To ensure that discussions and documents within the SMPTE 3D Task Force remain coherent, more than 80 3D terminologies were generated in four categories:

- **Display Types**
Defining terminologies such as *Stereoscopic Display Systems*, *Glasses-Based 3D Display*, *Non-Glasses-Based 3D Display*, and *Holographic Display*.
- **Image Format Representations**
Defining key terms such as *Image Pair*, *Stereoscopic Image Pair*, *Multiview*,

2D+Depth, *2D+Delta*, *Stereo+Depth*, and *Stereo+2Z*.

- **Basic Concepts**
Defining more than 40 3D concepts, including *3D Content*, *Absolute Parallax Transition Limit*, *Accommodation*, *Binocular Symmetries*, *Color Rivalry*, *Floating Window*, *Parallax*, etc.
- **Use Case Terms**
Defining the terms referenced in the use cases, such as *Formatting*, *Encoding*, *3D-Compatible Device*, *3D-Exclusive Content*, *3D-Compatible Device*, *3D Home Master*, *3D Source Master*, and *3D Distribution Data*.

Some of the terms have been adopted from previously published glossaries and documents. Almost all of the adopted definitions have been edited slightly from their referenced version. Other terms have been generated to be specifically unambiguous, especially in cases in which ambiguous terms have been popularly used with multiple definitions.

End-to-End 3D System

This section provides a conceptual signal flow diagram for 3D content distribution systems, as shown in **Fig. 1**. Discussion is

given on how 3D is created, mastered, and distributed to the home.

Use Cases

This section lists and describes Use Cases from various points of view, including viewers at home, different types of multi-channel video programming distributors (MVPD), broadcast stations, TV/cable networks, production/post-production companies, etc. More than 80 Use Cases with detailed description from these domains are listed, because they are expected to impose requirements on the format of the 3D Home Master. The Use Cases described in this section are intended to generate requirements for the format of the 3D Home Master. Additionally, each use case is rated on its relevance to the 3D Home Master and priority is given on whether it is important and near-term to 3D Home Master.

3D Home Master Requirements

Based on the use cases, the task force defined the minimum requirements for the specification for a single 3D Home Master that can be used to service any or all of the various downstream distribution channels. The requirements include nine categories:

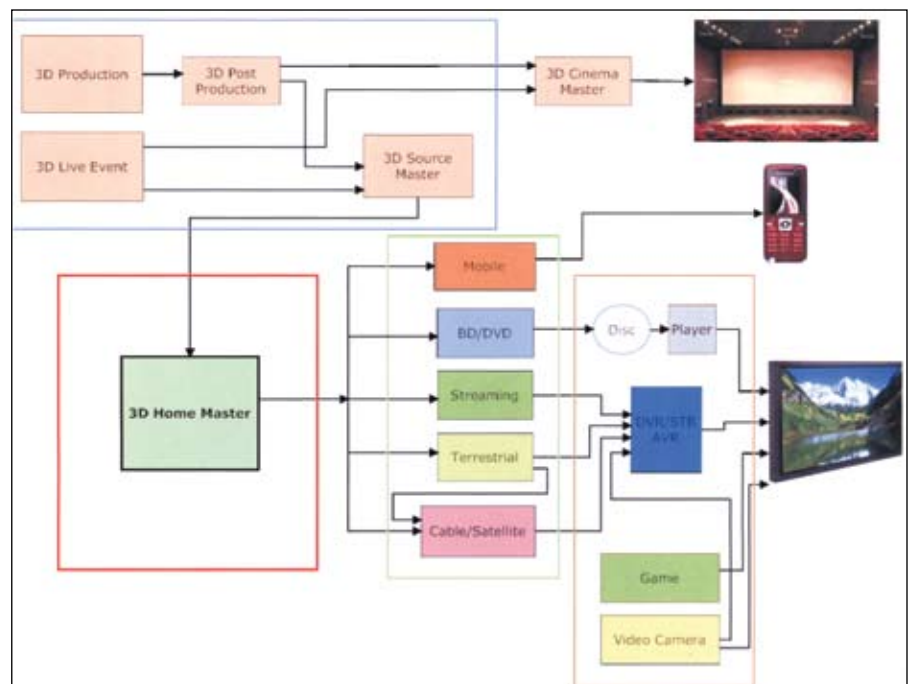


Figure 1. Conceptual signal flow diagram for 3D content distribution systems.



Reqmnt Number	Title	Detailed Requirement
1	Image Content	
1.1	Image Content Type	The image content shall consist of stereoscopic content from source material including film content, progressive video, or interlaced video in its native frame rate and aspect ratio.
1.2	Resolution and Frame Rate	<p>The image file definitions shall include video resolutions up to and including 1920 x 1080 and native frame rates up to and including 60p per eye view. Because 3D content may coexist with 2D content in various distribution scenarios and 2D content may be extracted from the 3D content for distribution, strong consideration should be given to existing related specifications (e.g., SMPTE 274M and 296M) when defining the image parameters of any future 3D Home Master specification.</p> <p>*Note: There was significant discussion within the Task Force whether the bit depth, spatial resolution, and/or color subsampling of each eye perspective of the stereoscopic content should be the same or can be different. Although binocular symmetry is encouraged, any future standards work should adequately study this issue in detail.</p>
1.3	Image Pairing	There shall be a left-eye and right-eye image for each stereoscopic image pair.
2	Audio Synchronization	There shall be a corresponding audio frame for each stereoscopic image pair.
3	Graphical Overlays	The 3D Home Master shall include a structure to optionally contain 3D depth information to enable realtime downstream composition with graphics (e.g., graphical menus). Also see Section 7.0, Metadata.
4	Subtitles	The 3D Home Master shall include a structure to optionally contain 3D depth information to enable realtime downstream composition with subtitles (either graphical subtitles or subtitles rendered by the playback device). Also see Section 7.0, Metadata.
5	Closed Captions	The 3D Home Master shall include a structure to optionally contain 3D depth information to enable realtime downstream composition with closed captions. Also see Section 7.0, Metadata.
6	Backward Compatibility with 2D	
6.1	Segment Insertion	The 3D Home Master shall be defined to anticipate that segment insertion may be used for local and client-side ad insertion as well as for the insertion of alternative footage (e.g., branching). Such segment insertion may include 2D segments inserted into 3D content streams, 3D segments inserted into 2D content streams, and 3D segments inserted into 3D content streams. The 3D Home Master shall be defined such that when transitions between 2D and 3D content occur, the transitions should be uninterrupted and smooth.
6.2	2D from 3D	The 3D Home Master shall be defined to optionally enable the ability to extract or generate a 2D version from the 3D version.
7	3D Metadata	For each metadata item outlined in the following sections, the 3D Home Master shall include a structure to reference the metadata item to the appropriate source image frame or image sequence. For example, this would enable synchronizing a frame of depth map to a particular image frame.



Reqmnt Number	Title	Detailed Requirement
7.1	2D Compatibility	The 3D Home Master shall include a structure to contain metadata to identify the method, if allowed, by which a 2D version can be extracted or generated from 3D content.
7.2	Stereoscopic Identification	
7.2.1	Stereoscopic Identifier	The 3D Home Master shall include a structure to contain an identifier indicating that the content is a 3D Home Master.
7.2.2	Start of Image Sequence Identifier	The 3D Home Master shall include a structure to include metadata identifying the start of the image sequence.
7.2.3	Stereoscopic Perspective Identifier	The 3D Home Master shall include a structure to include metadata for each image frame/field that identifies whether said frame is the left-eye or right-eye perspective.
7.2.4	Frame Pair Identifier	The 3D Home Master shall include a structure to include metadata for each image frame/field identifying a continuous frame/field count from the start of the image sequence identifier for each image sequence.
7.3	3D Depth Information	The 3D Home Master shall enable carriage of 3D depth information.
7.3.1	Depth Map	The 3D Home Master shall include a structure to optionally contain depth information for each image frame of at least one of the eye views (i.e., depth map of the 2D version). The depth map information, when provided, may have a spatial resolution equal to that of the source image content or less.
7.3.2	Depth Range	<p>A depth map can be utilized to calculate the depth range of each image frame, specifically the depth (z) position of the maximum negative parallax (object coming furthest out of the screen) and maximum positive parallax (object going furthest into the screen). However, in some instances it may be sufficient to only include the depth range for each image frame (and not the entire depth map). The 3D Home Master shall include a structure to optionally contain the depth range information.</p> <p>*Note: During discussion within the task force it was not clear whether the inclusion of the depth range was truly required, because, as noted above, if the 3D Home Master contains a depth map the depth range may be calculated from it. It has also been pointed out that it may be overly burdensome in all cases to include the depth map for each image frame into the 3D Home Master, and therefore it should be permitted to only store the depth range. Because no consensus has been reached within the task force we point this out with the expectation that any future standards work will adequately study this issue in detail.</p>
7.3.3	Position of Primary Attention	The 3D Home Master shall include a structure to contain optional information for each image frame indicating the 3D position of the primary object of interest. The method of representing the 3D position needs to be studied (e.g., x-y-z coordinate of center of the object of interest versus 3D volume of the object of interest).
7.4	Multi-view Rendering Support	The 3D Home Master shall be defined to include optional metadata in addition to depth maps to enable high-quality multi-view rendering.
7.4.1	Occlusion Information	The 3D Home Master shall include a structure to optionally contain information indicating portions of the image that are occluded behind foreground objects.



Reqmnt Number	Title	Detailed Requirement
7.4.2	Transparency Information	The 3D Home Master shall include a structure to optionally contain information indicating objects which are semi-transparent.
7.4.3	Resolution of Occlusion and Transparency Information	When present, the occlusion and transparency information shall have a spatial resolution equal to that of the source image content or less.
7.5	Composition Metadata	The 3D Home Master shall include a structure to optionally contain metadata for each image frame or image sequence associated with one or more potential downstream viewing environments, as well as the source camera. Specific metadata parameters include intended screen size, optimum viewing distance, optimum brightness level, intrinsic camera parameters (e.g., focal length), and extrinsic camera parameters (e.g., position and orientation of cameras). This is not an exhaustive list and should be studied in detail during any future standards creation process.
7.6	Floating Window Metadata	The 3D Home Master shall include a structure to optionally contain metadata for each image frame describing attributes of the floating window associated with the video content, including the location, color, and transparency.
8	Ancillary Metadata	The 3D Home Master shall be defined to carry ancillary metadata. Informative examples include the carriage of captions, subtitles, timecode, AFD data, and bar data. This is not an exhaustive list. Any future standards should adequately study these items in detail.
9	Evaluation Criteria	The specifications for the 3D Home Master generated to meet the above requirements should also meet the following general criteria.
9.1	Completeness	The specifications for the 3D Home Master shall meet the minimum requirements that have been presented by the task force, and satisfy all of the relevant use cases.
9.2	Extensibility	Future display technologies and distribution channels may require additional data/metadata than could be defined today. The specifications for the 3D Home Master needs to take into consideration this future growth and allow for extensibility that will minimize the impact on current systems.
9.3	Efficiency	The specifications for the 3D Home Master should consider the viability and efficiency of implementation, be it in terms of representation, storage, transport, computation, etc.
9.4	Human Readability of Metadata	The specifications for the 3D Home Master container format should consider readability of various elements of metadata where applicable.



These requirements will be used as guidelines for developing SMPTE 3D Home master standards.

Issues and Challenges

In addition to the use cases and requirements described in the report, the task force recognized that there are various unknowns, which may (in the future) have an impact on the format of the master package. Some of these factors and related references are discussed in detail in this section:

- Evolving Display Technologies
- Future Distribution Channels
- Production and Authoring Techniques and Needs
- Unexplored Psychophysical Characteristics of the Human Visual System

Recommendations of the Task Force

The task force developed the following recommendations:

SMPTE should undertake standardization effort to generate specifications for the 3D Home Master that meet the requirements listed. The intent of the standards creation should be to create a single 3D Home Master versus multiple masters.

SMPTE should establish liaisons as needed with other relevant standards development organizations (SDOs), as well as industry consortia and forums to:

- a. ensure compatibility/interoperability with the technical solution/specifications/standards being developed by those organizations;

- b. foster the use of the 3D Home Master (resulting from future SMPTE standardization activity) for content creation, storage, and ingest in downstream authoring and distribution;
- c. align terminology and concepts with the work of these organizations;
- d. identify gaps in standards required that fall within SMPTE's charter, and generate solutions for these gaps.

The types of organizations SMPTE should consider for liaison activity include those that consider distribution formats (broadcast, online, physical media), device interfaces, display technologies, etc., within the 3D content to the home eco-system.

SMPTE should continue to study and investigate solutions to the issues and challenges listed in this report in the course of developing a 3D Home Master standard. SMPTE should also embark on a review of how 3D content to the home affects the body of SMPTE publications.

The full report comprises 76 pages, including appendices, and is recommended for anyone seeking a comprehensive introduction to many aspects of 3D systems and the issues that need to be considered in planning for 3D to the home. It is available for download from the online SMPTE Store (<https://store.smpte.org>) for \$20.

CONCLUSION

The SMPTE 3D Home Master will be the cornerstone of the entire 3D content chain. It will provide high-level image formatting requirements for the source materials

authored and delivered by content developers. It will additionally provide requirements for the delivery of those materials to all distribution channels, from physical media to terrestrial, satellite, cable, and other streaming service providers.

As in the development of the 3D Home Master requirements, the SMPTE committee will work closely with other SDOs that will develop companion standards for complete end-to-end interoperability. SMPTE will also be reviewing existing standards in light of the 3D Home Master definition. When the committee finishes the specification work for a 3D home master, other SDOs will be able to leverage that work to move the content across various transports. This will be the first step in what will become the long-awaited realization of good-quality 3D content viewing in the home.

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William Zou has over 20 years experience in all aspects of digital video and audio systems engineering and standards development. His cross-industry experience includes TV engineering, cable television (CATV), broadcasting, content distribution over satellite, cable, internet protocol television (IPTV), packaged media and Hollywood movie studios. Since the late 1980s he has been an active participant and contributor in industry wide DTV standards development including the Advanced Television Systems Committee (ATSC), ACATS, BDA, SMPTE, the Institute of Electrical and Electronics Engineers (IEEE), and Standards Committee Telecommunications (T1). He is currently chair of the SMPTE Task Force on 3D to the Home. Zou is currently employed by DTS responsible for standards and business development. His corporate experience includes working for The Walt Disney Studios, PBS, General Instrument, Harmonic, Next Level Communications, and Tiernan Communications. He is the author or co-author of more than 40 publications and conference papers. Zou is a Fellow of SMPTE and a senior member of IEEE. He serves on the Board of Editors for the *SMPTE Motion Imaging Journal* and is an Associate Editor for the *IEEE Transactions on Broadcasting*.