



## **Specification**

**S-2014-004**

# **ACEScg – A Working Space for CGI Render and Compositing**

The Academy of Motion Picture Arts and Sciences

Science and Technology Council

Academy Color Encoding System (ACES) Project Committee

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Summary: This document specifies a recommended working space for CGI render and compositing to be used in conjunction with the ACES system.

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**Revision History**

Version	Date	Description
1.0	12/19/2014	Initial Version
1.0.1	04/24/2015	Formatting and typo fixes
	03/29/2016	Remove version number - to use modification date as UID

**Related Academy Documents**

Document Name	Description
S-2008-001	Academy Color Encoding Specification (ACES)
S-2013-001	ACESproxy – An Integer Log Encoding of ACES Image Data
S-2014-003	ACEScc – A Logarithmic Encoding of ACES Data for use within Color Grading Systems

## Table of Contents

NOTICES . . . . .	2
Revision History . . . . .	3
Related Academy Documents . . . . .	3
Introduction . . . . .	5
1 Scope . . . . .	6
2 References . . . . .	6
3 Terms and Definitions . . . . .	6
4 Specification . . . . .	7
4.1 Naming conventions . . . . .	7
4.2 Color component value encoding . . . . .	7
4.3 Color component value range . . . . .	7
4.4 Color component transfer function . . . . .	7
4.5 Color space chromaticities . . . . .	7
4.5.1 Color primaries . . . . .	7
4.5.2 White Point . . . . .	7
4.6 ACEScg . . . . .	8
4.6.1 Converting ACES2065-1 RGB values to ACEScg RGB values . . . . .	8
4.6.2 Converting ACEScg RGB values to ACES2065-1 RGB values . . . . .	8

## Introduction

SMPTE ST 2065-1:2012 defines a common color encoding method using half-precision floating point corresponding to linear exposure values encoded relative to a fixed set of RGB primaries. These primaries were designed to encompass the entire visual gamut. However, the algorithms commonly used to synthetically render imagery (CGI) have long used certain optimizations that are different than in typical color management scenarios and sometimes do not work well with very wide-gamut primaries. For example, in CGI rendering calculations, the RGB values of materials typically represent the percentage of light reflected. This is a different interpretation than in color science based on CIE colorimetry, where the RGBs are interpreted as tristimulus values with respect to a certain primary set. In other words, in CGI the RGB values often are used to describe a property of a material rather than the resulting color stimulus received by an observer.

This document describes the AP1 color primaries and their use as the basis of a 16-bit or 32-bit floating point working space for CGI rendering and compositing. These primaries are also the basis of the ACEScg working space, which was developed to better support color grading in the ACES work flow. They do lie slightly outside of the visual gamut, and do so in order to be able to encompass both the Rec-2020 gamut and the DCI-P3 gamut for a range of white points.

# 1 Scope

This document describes the translation of ACES2065-1 to/from ACEScg. ACEScg is intended as an appropriate working space for CGI rendering and compositing. ACEScg utilizes the AP1 color primaries for the purpose of rendering and compositing computer generated imagery (CGI). These primaries are the same as those used by the ACEScc working space.

# 2 References

The following standards, specifications, articles, presentations, and texts are referenced in this text:

SMPTE ST 2065-1:2012, Academy Color Encoding Specification (ACES)

SMPTE RP 177:1993, Derivation of Basic Television Color Equations

Academy S-2013-001, ACESproxy – An Integer Log Encoding of ACES Data

Academy S-2014-003, ACEScc – A Logarithmic Encoding of ACES Data for use within Color Grading Systems

# 3 Terms and Definitions

The following terms and definitions are used in this document.

## 3.1 ACES2065-1

RGB color encoding for exchange of scene-referred linear image data, between and throughout production and postproduction, within the Academy Color Encoding System. This color encoding is specified in SMPTE ST 2065-1:2012.

## 3.2 Rendering

The means by which computer models, surface texture and reflectance maps and lighting simulations are used to create images. Note: In the field of color science, the term “rendering” is sometimes used to refer to the conversion from a scene-referred to output-referred image state.

## 3.3 Compositing

The process by which multiple images (both computer generated and real) are combined into a final finished product. Compositing often involves making color adjustments to individual component images.

## 4 Specification

### 4.1 Naming conventions

The encoding of ACES specified in Section 4.6 shall be known as ACEScG.

### 4.2 Color component value encoding

ACEScG shall be stored as either 16-bit (IEEE binary16) or 32-bit (IEEE binary32) floating point values.

### 4.3 Color component value range

The value range for ACEScG color component values is  $[-65504.0, +65504.0]$ .

The chromaticity coordinates of the defined ACEScG RGB primaries (AP1) form a triangle on the CIE chromaticity diagram. ACEScG RGB values which express visible colors are represented by points within this triangle that also lie within the visual gamut.

The set of valid ACEScG RGB values also includes members whose projection onto the CIE chromaticity diagram falls outside the region of the AP1 primaries. These ACEScG RGB values include those with one or more negative ACEScG color component values; Ideally these values would be preserved through any compositing operations done in ACEScG space but it is recognized that keeping negative values is not always practical, in which case it will be acceptable to replace negative values with zero.

Values well above 1.0 are expected and should not be clamped except as part of the color correction needed to produce a desired artistic intent.

### 4.4 Color component transfer function

The color component transfer function directly encodes relative exposure values and is defined as

$$R = E_r, \quad G = E_g, \quad B = E_b$$

where  $E_r$ ,  $E_g$  and  $E_b$  represent relative exposure values that would be captured from the scene by the ACES Reference Image Capture Device (RICD) and  $R$ ,  $G$  and  $B$  are the resulting ACES color component values transformed to ACEScG using the methods specified in section 4.1.6.

### 4.5 Color space chromaticities

ACEScG uses a different set of primaries than ACES RGB primaries defined in SMPTE ST 2065-1. The CIE 1931 colorimetry of the ACEScG RGB primaries and white are specified below.

#### 4.5.1 Color primaries

The RGB primaries chromaticity values, known as AP1, shall be those found in Table 1.

	R	G	B	CIE x	CIE y
Red	1.00000	0.00000	0.00000	0.713	0.293
Green	0.00000	1.00000	0.00000	0.165	0.830
Blue	0.00000	0.00000	1.00000	0.128	0.044

**Table 1 – ACEScG RGB primaries chromaticity values**

#### 4.5.2 White Point

The white point shall be that found in Table 2.

	R	G	B	CIE x	CIE y
White	1.00000	1.00000	1.00000	0.32168	0.33767

**Table 2 – ACES RGB white point chromaticity values**

NOTE: The ACEScg white point is the same as the white point of ACES 2065-1.

## 4.6 ACEScg

The following functions shall be used to convert between ACES values, encoded according to SMPTE ST 2065-1, and ACEScg.

### 4.6.1 Converting ACES2065-1 RGB values to ACEScg RGB values

ACES  $R$ ,  $G$ , and  $B$  values shall be converted to ACEScg  $R$ ,  $G$ , and  $B$  values using the transformation matrix ( $TRA_1$ ) calculated and applied using the methods provided in Section 4 of SMPTE RP 177:1993.

NOTE: Equation 1 shows the relationship between ACES  $R$ ,  $G$ , and  $B$  values and ACEScg  $R$ ,  $G$ , and  $B$  values.  $TRA_1$ , rounded to 10 significant digits, is derived from the product of  $NPM_{AP1}$  inverse and  $NPM_{AP0}$  calculated using methods provided in Section 3.3 of SMPTE RP 177:1993. AP0 are the primaries of ACES specified in SMPTE ST 2065-1:2012. AP1 are the primaries of ACEScg specified in Section 4.5.

$$\begin{bmatrix} R_{ACEScg} \\ G_{ACEScg} \\ B_{ACEScg} \end{bmatrix} = TRA_1 \cdot \begin{bmatrix} R_{ACES} \\ G_{ACES} \\ B_{ACES} \end{bmatrix}$$

$$TRA_1 = \begin{bmatrix} 1.4514393161 & -0.2365107469 & -0.2149285693 \\ -0.0765537734 & 1.1762296998 & -0.0996759264 \\ 0.0083161484 & -0.0060324498 & 0.9977163014 \end{bmatrix}$$

$$TRA_1 = NPM_{AP1}^{-1} \cdot NPM_{AP0}$$

**Equation 1 – ACES2065-1 to ACEScg**

### 4.6.2 Converting ACEScg RGB values to ACES2065-1 RGB values

ACEScg  $R$ ,  $G$ , and  $B$  values shall be converted to ACES2065-1  $R$ ,  $G$  and  $B$  using the transformation matrix ( $TRA_2$ ) calculated and applied using the methods provided in Section 4 of SMPTE RP 177:1993.

NOTE: Equation 2 shows the relationship between ACES  $R$ ,  $G$ , and  $B$  values and ACEScg  $R$ ,  $G$ , and  $B$  values.  $TRA_2$ , rounded to 10 significant digits, is derived from the product of  $NPM_{AP0}$  inverse and  $NPM_{AP1}$  calculated using methods provided in Section 3.3 of SMPTE RP 177:1993. AP0 are the primaries of ACES specified in SMPTE ST 2065-1:2012. AP1 are the primaries of ACEScg specified in Section 4.5.



$$\begin{bmatrix} R_{ACES} \\ G_{ACES} \\ B_{ACES} \end{bmatrix} = TRA_2 \cdot \begin{bmatrix} R_{ACEScg} \\ G_{ACEScg} \\ B_{ACEScg} \end{bmatrix}$$

$$TRA_2 = \begin{bmatrix} 0.6954522414 & 0.1406786965 & 0.1638690622 \\ 0.0447945634 & 0.8596711185 & 0.0955343182 \\ -0.0055258826 & 0.0040252103 & 1.0015006723 \end{bmatrix}$$

$$TRA_2 = NPM_{AP0}^{-1} \cdot NPM_{AP1}$$

**Equation 2 – ACEScg to ACES2065-1**