

# Exploding World of Color Science

## Its Potential Impact on Graphic Arts

by David McDowell, NPES/Eastman Kodak

For most of us in the business of printing, the world of color science seems remote and not very applicable to what we do every day. The truth is that indirectly our industry will be one of the direct beneficiaries of much of the work that is going on today in the broad area of color science. And even more important, work in the areas of color science that will benefit printing and publishing is expanding dramatically.

Therefore, it is time for a tour of selected areas of the world of color science. Along the way we will look at some of the things that are going on that we need to be aware of, because they will impact us in the not too distant future. There are also some things that some of the more adventuresome folks may want to look into now.

### Color Management & the ICC

One area that is most visible to most of us is color management and the International Color Consortium, the ICC, so we just need a quick update. The ICC is continuing to work aggressively to help move color management from being a theoret-

ical concept to practical implementation in tools that we use daily.

At the recent ICC meeting in Scottsdale, Arizona, the relationship between the PDF/X International Standards and the ICC characterization data registry and ICC profiles was emphasized. Briefly, every

*“Our industry will be one of the direct beneficiaries of much of the work that is going on today in the broad area of color science.”*

PDF/X profile must point to either a characterized printing condition listed in the ICC registry or contain an ICC profile that colorimetrically describes the intended printing condition. In this way, the intended printed color of all PDF/X data is either directly or indirectly described. This is an excellent example of synergy between two different organizations as well as a major step forward for our industry.

The three areas receiving the most attention at the ICC meeting were the rewriting of the ICC Profile

specification in a form compatible with national and international standards procedures, color managed workflow descriptions and scenarios, and requirements that should be considered for a possible CMM specification.

From its earliest start the ICC has expressed a desire to someday move its specifications into international standardization. To help make sure that is possible, and to improve the clarity and ease of use of the standard before that occurs, in its spring 2002 meeting the ICC authorized the

Specification Editing group to start a rewrite based on the existing ICC Profile specification and the ISO procedures. Until the new version is approved, the existing document is the reference, and both versions will be maintained in parallel until the ICC is satisfied that they are technically equivalent.

The main thrust of the workflow discussions has been to develop a general understanding of color managed workflows and how they can be applied in many different industry sectors. Such an under-

standing will help define and develop implementation strategies for both users and developers, but, more important, will help identify areas in which the current ICC architecture and specifications need modification or strengthening.

These workflow discussions are, in turn, building on the work of TC42/JWG22 and CIE TC8-05, both of which will be discussed later. One of the approaches being used is to define perceived problems and then identify the available solutions and/or specification changes necessary to allow reasonable solutions.

The CMM is the generic name given to the computational engine that processes the image data based on instructions contained in the associated ICC profiles. All CMMs must properly use all ICC defined profile tags but may also use privately defined tags. Many of the baseline capabilities and requirements are defined as part of the profile specification, but there is a growing desire to more explicitly define a default set of CMM requirements to ensure interoperability.

### **CIE Division 8**

CIE is one of those names many of us have heard, but are hard pressed to explain or to define. CIE, from its French title of Commission Internationale de l'Eclairage (International Commission on Illumination), is an organization devoted to international cooperation and exchange of information among its member countries on all matters relating to the science and art of lighting. However, this also includes understanding color vision, which for us is the more important aspect of their work. Division 1, Vision and Color, and Division 2, Measurement of Light and Radiation, have provided us with most of the tools, such as tristimulus values, CIELAB color space, etc., that we use to evaluate color.

*All CMMs must properly use all ICC defined profile tags but may also use privately defined tags. Many of the baseline capabilities and requirements are defined as part of the profile specification, but there is a growing desire to more explicitly define a default set of CMM requirements to ensure interoperability.*

CIE Division 8, Image Technology, was formed in 1998, at the urging of the imaging technical community, to enable the CIE to better address the needs of the imaging industry and specifically the emerging world of color management. Division 8 consists of seven Technical Committees (TCs) which are:

- TC8-01 Colour Appearance Modeling for Colour Management Applications,
- TC8-02 Colour Difference Evaluation In Images,
- TC8-03 Gamut Mapping,
- TC8-04 Adaptation Under Mixed Illumination Conditions,
- TC8-05 Communication of Colour Information,
- TC8-06 Image Technology Vocabulary, and
- TC8-07 Multispectral Imaging.

While the tasks of the Division 8 TCs are somewhat more theoretical and abstract than many of us are used to, they indirectly offer some very practical help for day-to-day problems in our industry.

All color management concepts, including that of the ICC, are based on the use of various aspects of color appearance modeling. The first CIE color appearance model, CIE 1997 Interim Colour Appearance Model (Simple Version),

CIECAM97s, was published in late 1998. TC 8-01 has been studying updates to that model and is in the process of preparing an updated version that is currently known as CIECAM02. At the same time TC8-03 has been looking at various gamut mapping models which are an integral part of appearance modeling.

The work of both of these TCs is being followed by the ICC which will build on all of the CIE improvements on appearance modeling that are applicable to the ICC model. These in turn will improve both the performance and interoperability of the color management applications we use as production tools.

TC8-02 is attempting to develop both a procedure and a metric to compare the measured colorimetry of two images and predict the probability that a typical observer will say they do, or do not, match. While this work is currently focused on “detectability” of mismatch, and we in the graphic arts are more focused on the “acceptability” aspects of matching. We believe the work in TC8-02 will lead to a useful tool that can be applied to both aspects of the issue. Possibly even provide the beginning of a proof acceptance criteria based on measurement data alone.

It is not uncommon in graphic arts to compare an image on the monitor with one in a reflection print illuminator, when both are in the field of view. Of course they both never have the same white point. How

does our visual system accommodate to two different white references and what color shifts occur as a result. TC8-04 is trying to determine what our adoption is under such conditions and what effect that has on our judgement of either or both images. Again, this is a very practical issue for which little knowledge exists and another possible input into a color appearance model or possibly a set of practical criteria that can be used in setting up such viewing conditions.

TC8-05 is working to establish a family of criteria that can be used to evaluate the applicability of individual color spaces for various applications. There are many arguments about which RGB space is best, whether RGB is better than CMYK, or if we should be using CIELAB. The results of the TC8-7 work should provide a consistent way to trade-off color space volume, color-error, bit-depth, etc., to allow the best decision to be made for specific applications. However, in real world applications, both practical workflow needs and the results of these evaluation criteria will need to be balanced to find the preferred solution.

TC8-07 is the newest Technical Committee in Division 8, and it is just getting started. Its charter is to “study, develop, and recommend encoding techniques and data formats for the exchange of multispectral images, and to provide test procedures for the evaluation of multispectral imaging systems.” It will be looking at the effect of using more than three channels of imaging data and the potential benefits that it might bring.

#### **TC42 and TC130**

Our traditional standards committees are also doing color related work. Much of this is occurring in Joint Working Groups (JWGs) between TC42 and TC130.

TC42/JWG 20 is developing the multi-part standard ISO 17321 which includes specifications and procedures for the color characterization of digital still cameras (DSC). The standard will include options for using either physical targets or spectral illumination techniques and recommended methods for determining transforms from raw DSC data to scene-referred image data. This is another piece of the whole color management environment.

The term “scene-referred” comes from Part 1 of ISO 22028, *Photography and graphic technology — Extended colour encodings for digital image storage, manipulation and interchange*, being developed by TC42/JWG23. Part 1 lays out the Architecture and requirements and introduces a very significant concept that is essential to many color management applications. That concept is the idea of a image state and the recognition that there are scene image spaces and picture or output image spaces and that there is no simple transform between the two. This is further complicated by the fact that we often use the same color encoding for both. A typical example is that if we had a digital still camera that exactly captured the colorimetry of every object in the scene we could not, and indeed would not want to, replicate the scene colorimetry in a print of the scene. Yet we often report and talk about the colorimetry of the reproduction and the original using similar metrology and data encoding. Again as color management systems incorporate digital still camera input, and build transforms to typical output spaces, these concepts become critical to enable a common understanding of data between applications.

Although not directly a color issue, TC42/JWG21 is continuing to revise the ISO 5 series of densitometry standards.

Of particular interest is the revision of *ISO 5.3, Photography and graphic technology—Density measurements—Part 3: Spectral conditions*. The current draft is based on the concept of spectral products that are essentially filter functions. The revised draft will be based on computations based on spectral data. While numerical differences are small, the theoretical base and traceability issues are significantly different. Suffice it to say we will soon have clearly defined procedures to compute density from spectral measurements.

TC130 recently approved *ISO 12646, Graphic technology—Displays for colour proofing—Characteristics and viewing conditions*. The ability to match color images displayed on monitors (often called a soft proof) to the images produced when the same digital file is proofed and printed is increasingly expected in graphic arts. Obtaining such a match is not simple. The primary purpose of ISO 12646 is to make recommendations for soft proof viewing conditions. However, the appearance of a color image on a monitor is influenced by many physical factors other than controlled viewing conditions. Among the most important of these are uniformity, convergence, size and resolution (in order to permit rendition of the proof as close to its normal size and with the finest detail visible on the hard copy at normal viewing distances), freedom from flicker, the calibration of the display and the settings of its display driver software. So, to be acceptable as a proofing system which provides a reasonable level of image quality the display must also exhibit acceptable quality of these properties. Therefore, ISO 12646 also specifies minimum requirements for factors such as uniformity, convergence, refresh rate, size and spatial resolution.

TC130 has just put *ISO 12640-2, Graphic technology—Prepress digital data exchange—Part 2:XYZ/sRGB encoded standard colour image data (XYZ/SCID)* into DIS (final approval) ballot. This set of images are constrained to fit within the sRGB color gamut. They are intended to complement the popular CMYK/SCID image set of ISO 12640 (soon to be re-designated ISO 12640-1). However, to ensure that the two image sets are not confused, different images were selected for the new image set. These should be available for widespread use shortly after the ballot closes in March 2003.

As part of the development of ISO 12640-3, a large gamut set of SCID images which is the third part of the SCID image sets, there was a need to define the gamut limit for expected colors. At the same time the ICC has been investigating the pros and cons of defining a gamut limit for the PCS to be used in gamut mapping applications. This has led to the possibility that together the ICC and TC130 can agree upon and standardize a reference gamut of real world reflection colors. This could provide a useful reference in many different applications. Too soon to tell exactly where this will end up, but an example of the synergy we are seeing between the various groups involved in color, particularly as it has an impact on the printing and publishing industry.

*ISO TR 16066, Graphic technology—Standard object colour spectra database for colour reproduction evaluation (SOCS)*, is currently in final preparation for publication. It provides an exhaustive collection of the spectral reflectances (colors) of existing objects and includes a database containing more than 50,000 items. This report also details the extraction from the data of 365 samples and their classification into sets, of which there are two types,

“typical sets” and “difference sets.” “Typical sets” refers to sets of typical spectral reflectances and transmittances of objects as classified into a number of different categories. “Difference sets” refers to sets of metamers whose tristimulus values are roughly typical but whose spectral values are significantly non-typical.

I3A (International Imaging Industry Association) is the new name for the trade association that supports the Photographic Industry. It is the secretariat for ISO TC42 and for the ANSI standards committees in photography. One of these committees, IT10, has approved three extended

This conference has become the leading venue for discussions of color science and engineering. It's not of interest to most in our industry, but is heavily attended by the ICC folks. Clearly it is something to monitor as a harbinger of things to come.

Some titles of papers that may have future impact on our industry were: *Observer Preferences and Cultural Differences in Color Reproduction of Scenic Images; Frequency Analysis and Synthesis of Skin Color Textures; Color Calibration of LCDs; ICAM, The Next Generation Color Appearance Model; and New Uniform Colour Spaces.*

*While many of these topics seem esoteric and way out, remember it was only four years ago that CIE Division 8 was formed and the first CIE color appearance model was published. The world of color science—most important, the world of practical color science—is moving more rapidly today than it ever has before.*

gamut color space standards for photographic data application. These are: I3A 7466, *Electronic Still Picture Imaging—Reference input medium metric RGB color encoding (RIMM-RGB)*; PIMA 7666, *Electronic Still Picture Imaging—Reference output medium metric RGB color encoding (ROMM-RGB)*; and PIMA 7667, *Electronic Still Picture Imaging—Extended sRGB color space e-sRGB*. As TC42, the TC42/TC130 JWG's, and the ICC get more involved in extended gamut color spaces as work or data exchange spaces, I am sure we will be hearing more about these color spaces.

### Color Imaging Conference

Many activities noted were the subject of IS&T's 10th Color Imaging Conference ([www.imaging.org](http://www.imaging.org)) recently held in Scottsdale, Arizona.

While many of these topics seem esoteric and way out, remember it was only four years ago that CIE Division 8 was formed and the first CIE color appearance model was published. The world of color science—most important, the world of practical color science—is moving more rapidly today than it ever has before.

### Summary

The world of color science can be daunting. A lot is going on, much of which can have a direct impact on the printing and publishing industry. This has been a brief look at some of the more significant recent activities.

If anyone would like pointers to follow up on specific issues, please contact me at [mcdowell@npes.org](mailto:mcdowell@npes.org) or [mcdowell@kodak.com](mailto:mcdowell@kodak.com). 