A Closer Look at Flat-Panel-Display Measurement Standards and Trends

The VESA FPDM standard is widely recognized as the best display-measurement standard. Take a guided tour of the formidable standards landscape and learn how less-popular standards and specifications measure up and where the "measurement standards world" is headed.

by Phil Downen

THE STANDARDS for measuring flat-panel-display (FPD) performance have kept pace with the advancements made by FPD technology during the past decade. While most standards define display resolutions, timings, and electrical and mechanical interfaces, others tackle front-of-screen optical measurements with varying degrees of success. Those of us responsible for quantifying display performance generally agree the VESA Flat Panel Display Measurements (FPDM) standard has become the de facto "standard of standards" serving the display industry because it provides a comprehensive catalog of versatile optical measurements and informative technical discussions well-grounded in solid metrology.

No other standard offers so much practical information organized so well. However, other standards and specifications still play important roles in the display industry and, in fact, are harbingers of an emerging trend in holistic application-specific standardization.

***Phil Downen** is Product Manager for Flat Panel Display Performance Measurement (FPM) Systems at Westar Display Technologies, Inc., 4 Research Park Dr., St. Louis, MO 63304; telephone 636/300-5102, e-mail: downen@westar.com. This article expands upon a paper originally presented at the ADEAC '05 conference held in Portland, Oregon.*

We begin our tour by reviewing the treatment of optical measurements of four popular standards: VESA FPDM, ISO 13406-2, TCO '05, and SPWG 3.5. The vital statistics for these standards are summarized in Table 1.

It is important to note the VESA, ISO, TCO, and SPWG standards come from very different organizations and were born of contrasting charters and influences. For example, the VESA FPDM and SPWG documents differ from the others in that they are not compliance standards insofar as they do not prescribe measurement quality thresholds or pass/fail criteria. So, while the display product itself might be marked "TCO '05 certified" or "ISO 13406-2 compliant," only the underlying measurement methods might be said to be "VESA FPDM compliant."

Origins and Applicability of Standards

VESA Flat-Panel-Display Measurements (FPDM) Standard. Originally released as Version 1.0 in May 1998 (with a bright yellow cover) by the FPDM Working Group of the VESA Display Committee, this standard was developed to fill a void in FPD metrology. To that point, much had been written about what to measure, but nothing had been published on how to measure it and avoid the pitfalls of bad metrology. Key attributes of the FPDM standard are its faithfulness to sound metrology (complete with a thorough treatment of photometry, colorimetry, measurement diagnostics, and technical discussions), a menu-like organization of robust measurements, and strict avoidance of compliance language. To quote its introduction, "What people do with the results is their own business, but we wanted to make sure that it was measured correctly."

Re-released in June 2001 (with a hot pink cover) by the then newly formed Display Metrology Committee of VESA, Version 2.0 incorporated corrections and clarifications and expanded test-item coverage. While most frequently applied to consumer active-matrix liquid-crystal displays (AMLCDs) such as notebooks, monitors, TVs, *etc.*, its methods and principles extend across industrial, military/aerospace, and medical applications, regardless of display technology, with only occasional caveats. This standard enjoys widespread acceptance and is often referenced.

ISO 13406-2, "Ergonomic Requirements for Work With Visual Displays Based on Flat Panels – Part 2: Ergonomic Requirements for Flat-Panel Displays." Released in December 2001, this standard was prepared by the International Organization for Standardization Technical Committee (ISO/TC) 159, subcommittee SC 4. It is based on the cathode-ray-tube (CRT) measurement work of ISO 9241-3, but was adapted to address the unique requirements of FPDs.

Table 1: A Summary of the VESA FPDM 2.0, ISO 13406-2, TCO '05 Notebooks, and SPWG 3.5 standards

	VESA FPDM 2.0	ISO 13406-2	TCO'05 Notebooks	SPWG 3.5
Release Date	June 2001	December 2001	June 2005	March 2005
Available from	www.vesa.org	www.iso.org	www.tcodevelopment.org	www.spwg.org
Price	US$40	US$170	Free	Free
Applicable to	FPD measurement methods and metrology	Flat-panel-monitor ergonomic classification	Notebook-FPD visual performance, ergonomics, emissions, and ecology	Notebook-FPD mechanical and electrical specifications
Important to	All parties concerned with display-measurement methods and metrology	Those specifying or procuring monitors for the office environment	Notebook purchasing agents with interest in ergonomic and environmental issues	Notebook engineering and panel-procurement groups concerned with electrical and mechanical interfaces
Total Pages	332	147	106	58
Optical Measurement Pages	304	138	37	14
Next Release	Version 3.0 – 2006	ISO 9241-300 – 2006	TCO '07 – 2007	SPWG 4.0 – early 2006

As the title indicates, ISO takes a decidedly ergonomic approach to display measurements by emphasizing physical aspects of the human–display interface. The standard includes extensive treatment of viewer–screen geometry (head position and viewing direction) and addresses character-legibility and reflection characteristics.

The ISO standard is not primarily about measurements, but rather it is about display classification in terms of viewing direction, contrast and color, reflection performance, and pixel faults. The overall aim is to determine the suitability of a display for the office environment. While familiar underlying measurements support this goal, they can be understood and implemented only after penetrating a heavy layer of ergonomic notation and vernacular.

Nonetheless, compliance requirements based on this standard are on the rise mainly due to European market mandates. Most display OEMs and Asian panel makers are facing increasing downward pressure to understand, apply, and report measurements found in ISO 13406-2.

TCO '05. Recently released in two parts (for notebooks and for desktops), TCO '05 is the fifth release by the TCO (Swedish Confederation of Professional Employees), preceded by TCO '92, TCO '95, TCO '99, and TCO '03.

Both parts of the new TCO '05 address a wide variety of compliance mandates including visual ergonomics, electromagnetic emissions, electrical safety, ecology, and energy efficiency. Past versions contained little in terms of detailed optical-measurement requirements and methods.

The new TCO '05 Desktops standard leans heavily on the limited visual ergonomics of the TCO '03 FPD VDU standard. However, the new TCO '05 Notebooks standard expands upon the TCO '03 content, adding method detail and updated mandate specs.

The TCO tack is unique because it alone seems to touch, albeit lightly, on all aspects of display usage and life cycle, giving equal weight to ergonomic, electrical, optical, and environmental concerns. Although not strictly mandatory, TCO labeling of notebooks and monitors for the European Union (EU) is commonplace since this standard has been endorsed by the EU OSHA (European Agency for Safety and Health at Work). About one-half of the displays produced in the world today are TCO labeled.

SPWG 3.5. Released in March 2005, the Standard Panel Working Group (SPWG) Version 3.5 specification follows versions 1.0, 2.0, and 3.0. Formed in 1999 with members from Compaq, Dell, Hewlett-Packard, IBM, and Toshiba, the SPWG aimed to curb the proliferation of unique notebook-display panels by identifying and promoting only the most popular mechanical and electrical interfaces.

True to its charter, the specification mainly defines standard panel resolutions, aspect ratios, mechanical dimensions, electrical interfaces, and inverter integration. Common front-of-screen optical measurements – largely based on the VESA FPDM methods – and electrical-power measurements are concisely described. More than 60% of all notebook panels shipped today are SPWG compliant.

What's In a Name?

Table 2 is a cross-reference linking common measurement names with each standard's applicable section numbers. Three important caveats apply:

1. Measurement names are generic but are often implemented differently across the standards.
2. Recommended equipment, environmental conditions, optical instrumentation, and test patterns vary.
3. Data analysis, interpretation, and reporting vary.

Referring to the cross-reference, we can see that not every measurement is addressed in each standard. Moreover, many measurements are defined and implemented differently. For example, the venerable "uniformity" measurement (a common metric of full-screen luminance and/or color consistency across the display surface) is implemented four different ways by the VESA, ISO, TCO, and SPWG standards.

Table 2: Display-Measurement Standards Cross-Reference

Standard	VESA FPDM 2.0	ISO 13406-2	TCO '05 Notebooks	SPWG 3.5
Equipment and Set-Up Requirements	301	8.3, 8.4	B.2.0	6.1
Center Screen Luminance	302-1, -2, -3, -4	8.7.19	B.2.3.1	6.2, 6.4
Luminance & Contrast Ratio Uniformity	306-1, -2, -3	8.7.19	B.2.3.2	6.2, 6.4
Correlated Color Temperature	306-1	–	B.2.6.1	–
Color Uniformity	306-4	8.7.5	B.2.6.2	–
Color Gamut	302-4	8.7.5, 8.7.27, 8.7.29	B.2.6.3	6.5
Contrast Ratio	302-3, 306-3	8.7.15	B.2.4.2	6.3
Detail Contrast Ratio	303-5	–	B.2.4.1	–
Shadowing (Cross Talk)	303-4	–	–	–
Response Time	305-1	8.7.21, 8.7.23	–	6.8
Flicker	305-4	8.7.24	–	–
Image Retention	305-2	–	–	6.9
Warm-Up Time	305-3	–	–	–
Fill Factor	303-3	8.7.9	–	–
Luminance & Contrast Ratio *vs.* Viewing Angle	307-2, -3, -4, -5	8.7.14, 8.7.15	B.2.3.3, B.2.4.2	6.7
Color *vs.* Viewing Angle	307-1, 307-6	8.7.5	B.2.6.4	–
Reflection Testing	308-1, -2, -3, -4, -5	8.7.17	B.2.5.2	–
Pixel Defects	303-6, 303-8	8.7.20	–	9.0
Gamma	302-5A	–	B.2.6.5	6.6

Note. Blank entries (–) indicate the measurement is not explicitly addressed.

Luminance Uniformity: Four Different Ways

First, the VESA FPDM luminance uniformity measurement is described in section 306-1 ("Sampled Uniformity of Color and White") and requires that the light-measurement device (LMD) be positioned at five (or optionally nine) locations perpendicular to the screen surface (see Fig. 1 for a layout of the VESA uniformity measurement).

Measurement locations include the center point plus four (or eight) peripheral points that are always 10% of screen width from the sides and 10% of screen height from the top and bottom. As with all VESA FPDM measurements, only the method and reporting format are prescribed; no pass/fail criteria are imposed. A simple "Non-Uniformity" metric is calculated from the five (or nine) measured points as

$$\text{Non-Uniformity} = 100\% \, [1 - (L_{min} / L_{max})],$$

where L_{min} is the minimum and L_{max} is the maximum luminance measured. Here, we can see that if $L_{min} = L_{max}$, the non-uniformity equals zero. If L_{min} is 10% less than the L_{max} ($L_{min} = 0.9L_{max}$), then the non-uniformity becomes 10%, which is fairly intuitive.

A second implementation is found in the ISO standard and is illustrated in Fig. 2. The luminance-uniformity measurement description begins in clause 8.7.19, "Luminance Uniformity," but requires mastery of clauses 7.19 (uniformity design requirements), 7.2 (design viewing direction), 8.4.1 (test directions), and 8.4.2 (standard measurement locations) to fully understand and implement the test. The LMD geometric set-up is complex and depends on the display size, technology, and design viewing distance and direction (the optimal viewing eye position as specified by the display maker).

In the simplest scenario, the LMD is aimed at three points on the screen surface (center point and two others selected from 11 standard locations) through the design eye-point. The "Uniformity" metric is computed as the simple ratio of the maximum to the minimum luminance among the three measurements as

$$\text{Uniformity} = (L_{max} / L_{min}).$$

This uniformity ratio is assessed against a maximum allowed ratio called a compliance threshold, which varies from 1.3 to 1.7, depending on the angular separation between measurement locations (closer locations mandate a lower threshold).

Recall that the ISO standard is targeted at office-space applications such as PC monitors.

Therefore, ambient illumination (precision light sources illuminating the display face at specific angles) must also be set up for this basic uniformity test.

The TCO luminance-uniformity measurement can be found in paragraph B.2.3.2 and prescribes a third implementation as illustrated in Fig. 3. Measurements perpendicular to the screen are only made in the four corners of the display. Measurement locations are specified in terms of a 1° angular subtense spacing from the edges. This means the spot locations vary, depending upon the measurement distance, which is generally 1.5 times the screen diagonal. Similar to the ISO standard, TCO prescribes a compliance threshold (fixed at 1.5) for the maximum-to-minimum luminance ratio (referred to as "Luminance Variation") that is computed from the four measured values as

$$\text{Luminance Variation} = (L_{max} / L_{min}).$$

Finally, the SPWG luminance-uniformity measurement is found in section 6.4 and offers a fourth implementation of this test as shown in Fig. 4. Measurements perpendicular to the screen are made at 13 points arrayed across the display surface. Nine locations (similar to the VESA nine points) are specified at a fixed 10 mm from the edges and at the center point. Four additional points are included at ±25% of the screen height and width from the center.

A "Luminance % Uniformity" metric is computed from the 13 measured values as

$$\text{Luminance \% Uniformity} = 100\%[(L_{max} - L_{min}) / L_{max}].$$

Note, in this case, 0% actually indicates a perfectly uniform display ($L_{max} = L_{min}$) among the points measured), and thus this metric would more aptly be named "Luminance % Non-Uniformity."

Disharmony or Application-Specific Influence?

The discord evident in the four uniformity implementations is due partly to differences in the authoring organization's charters and partly to application-specific influences. As for charter differences, the VESA FPDM committee set out to produce an application-independent standard that informs users in the areas of robust measurement methods, laboratory practices, and metrology discipline. Their decision to define perpendicular luminance measurements positioned ratiometrically on the display surface was made to simplify the equipment set-up and establish a repeatable metric that could be easily achieved.

The ISO committee focused on how the display actually appears to the user and established the design eye-point requirement, which is much more difficult to set up, so measurements would be taken from the user's vantage point. This arrangement measures non-uniformity resulting from viewing-angle characteristics as well.

The TCO '05 Notebooks standard, born of European authorship similar to the ISO standard, emphasizes low environmental impact (including mandates for power efficiency, materials biodegradability, and electro-magnetic emissions) and addresses a fairly short list of basic optical measurements such as luminance uniformity, viewing angle, and reflection characteristics.

As for application influences, the ISO standard endeavors to prescribe measurements that are representative of the typical ergonomic relationship between the user and a flat-panel monitor. Hence, a great deal of care is given to the definition of real-life viewing directions and ambient-lighting conditions as

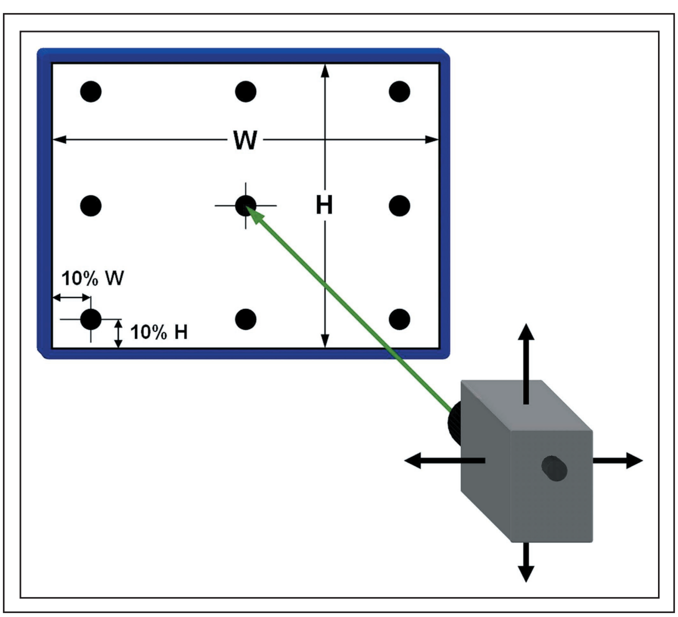

Fig. 1: VESA FPDM standard, section 306-1, "Sampled Uniformity & Color of White Measurement," requires the LMD to be positioned in five (or optionally nine) positions perpendicular to the screen surface.

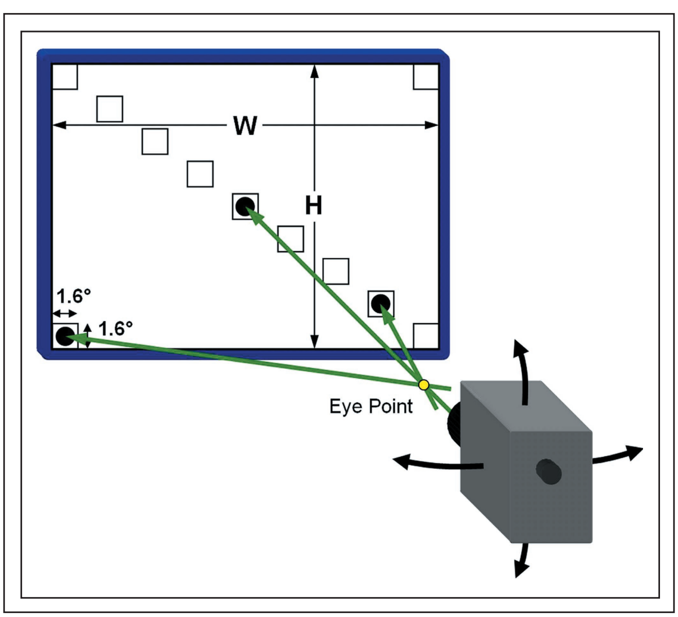

Fig. 2: ISO 13406-2 standard, clause 7.19, "Luminance Uniformity Measurement," requires that the LMD be aimed at minimally three points on the screen surface through a single design eye point.

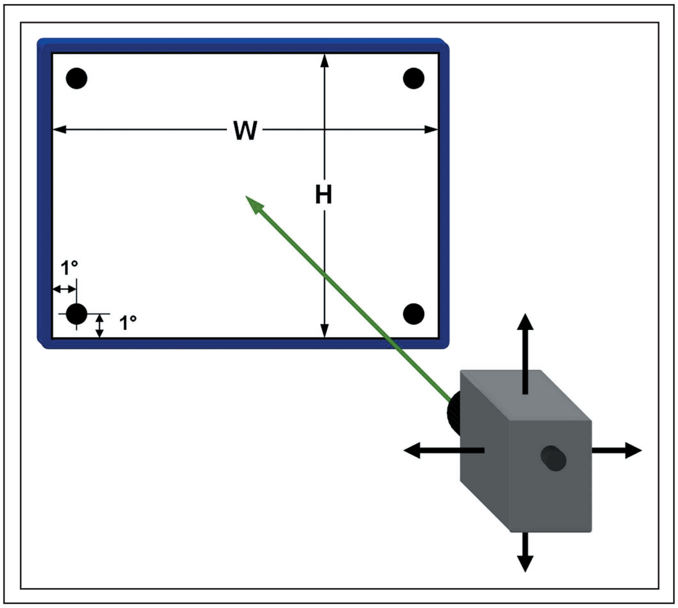

Fig. 3: TCO '05 Notebooks standard, paragraph B.2.3.2, "Luminance Uniformity Measurement," requires the LMD to be positioned in four corner positions perpendicular to the screen surface.

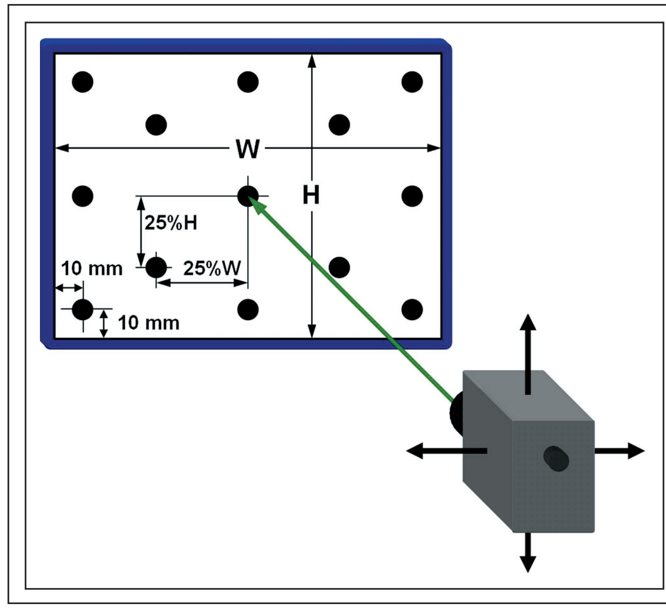

Fig. 4: SPWG standard, section 6.4, "White Uniformity Measurement," requires that the LMD be positioned in 13 positions perpendicular to the screen surface.

prerequisites for any optical measurements. The SPWG specification calls out panel measurements important to the notebook, including response time and power consumption.

Because of fundamental differences in charter, committee membership, and basic writing styles, these standards diverge in aspects beyond their measurement inventories such as methodology, notation, terminology, and organization. In short, these documents were written by independent organizations at different times for different purposes. Thus, each stands alone and should be applied appropriately as agreed upon by all interested parties.

The Outlook for Each Standard

Each standard we reviewed continues to evolve along the line of its original charter. The measurement methods and tools contained in the VESA FPDM standard continue to serve the entire industry by providing a set of robust optical measurements from which to draw. The ISO, TCO, and SPWG documents trend toward application specifics going beyond basic measurements to address ergonomic, environmental, interface, and form-fit-function issues. We can look forward to the following from each standard in the next year or two:

- Version 3.0 of VESA FPDM (with a bright green cover) is planned for 2006 and will include new measurements for motion artifacts and new diagnostics. Look for updated treatment of reflection tests and totally new content on motion-picture response-time methods. Version 3.0 will also be re-written using terminology consistent with the CIE.
- ISO 13406-2 has been revised and merged with ISO 9241 parts -3, -7, and -8. With a broadened applicability beyond monitors, it is now known as Draft International Standard 9241-300. It will emerge from committee in late 2006 following the imminent acceptance vote and final edit.
- TCO '05 is still new and will stand until early 2007 when TCO '07 is issued. Expansion will likely address wireless local-area-network (LAN) emissions requirements and basic temporal measurements such as response time and flicker.
- SPWG 4.0 is planned for early 2006 and will address new panel sizes and subject matter including glossy panels, RGBW color measurements, perceived resolution, and touch-screen metrology.

The Need for Application-Specific Standardization

As our tour winds down, we have one more stop – a scenic overlook called "The future of display standards in an increasingly commoditized market."

It is easy to imagine how the display food chain would want to use various parts of the standards we surveyed – picking and choosing those sections most suitable for solving quality problems. One addresses optical measurements very well, another dictates electrical and mechanical specifications, and still another identifies key environmental or ergonomic requirements. Now, place all these standards on a table between a major PC maker and its eight or so Asian panel vendors and several contract manufacturers, then invite the EU regulatory agencies to the meeting and see what happens. That dizzy feeling in your head is called standards vertigo.

While each standard we have examined serves a slice of the food chain's needs, none provides the comprehensive, holistic answer to the unique quality challenges of any given market (notebook, monitor, TV, handhelds, *etc.*). What is needed is a unified display qualification standard (per major application) that addresses

1. Component-level specification of the display module (basic electrical, optical, and mechanical specs).
2. Unique system integration requirements of the display platform (electrical, mechanical, and thermal reliability).
3. Regulatory agency requirements (power efficiency, EMI, environmental, and safety).
4. Electro-optical pass/fail criteria in the form of standardized test methods and compliance thresholds.

No doubt the proposition of absolute display-quality compliance thresholds is controversial because it raises concerns about vanishing technical discriminators and competition. But in applications that have become commoditized, such as the notebook PC, the path of compliance thresholds is a natural progression. This is because the changing notebook market has steadily shifted ownership of the definition of display quality from the original design manufacturer (ODM) – read as "notebook maker" – to the collective customer comprised of corporate, governmental, academic, and private organizations as well as individual consumers. For an in-depth look at the role of display standards in the notebook-PC market, refer to or contact the author for a copy of the ADEAC '05 paper "Meeting the Product Qualification Needs of a Rapidly Growing Industry," co-authored by Dell and Westar Display Technologies. In it, a behind-the-scenes look at the notebook-PC display supply chain and an introduction to Dell's "Vendor Self-Qualification" (VSQ) program is provided.

A Vision of the Future

A closer look at these four popular standards and how they address FPD optical measurements reveals more differences than similarities. It is clear that the display standards world is currently fragmented. Meanwhile, major display market segments (led by notebooks, monitors, and TVs) are ready for comprehensive application-specific standards. Their ongoing transition to commodity status means that these segments will exert increasing pressure on the standards bodies for holistic solutions that comprehensively address the display qualification process from beginning to end.

The ISO, TCO, and SPWG documents are examples of first-generation application-specific standards. These could be built upon to address the needs of the broader display food chain, thereby helping panel vendors and ODMs to operate more efficiently by qualifying panels more quickly. This goal can only be achieved when industry kingpins (with supplier management insight) cast the vision, set up the framework, and invite industry experts and standards bodies to participate in the process. Any resulting new standards should maintain traceability to the methods and metrology foundation already defined in the VESA FPDM standard.

At this time, no formal industry-wide effort is under way to produce such holistic standards. However, a sign of things to come may be found in Dell's recently publicized VSQ philosophy and the supporting work of Westar Display Technologies. The VSQ foundational work is extensible to lower tiers in the supply chain and is transferable to similar FPD-centric products such as monitors and TVs.

We invite other industry experts and the standards bodies to join the march toward comprehensive application-specific standards that not only address form-fit-function, electrical interfaces, and optical measurements, but also tackle end-product system-integration issues and recognize the parameters of each application's market status. We have finally entered the brave new world of commoditized high-information-content displays, and a fresh, comprehensive look at our display standards is needed. ■