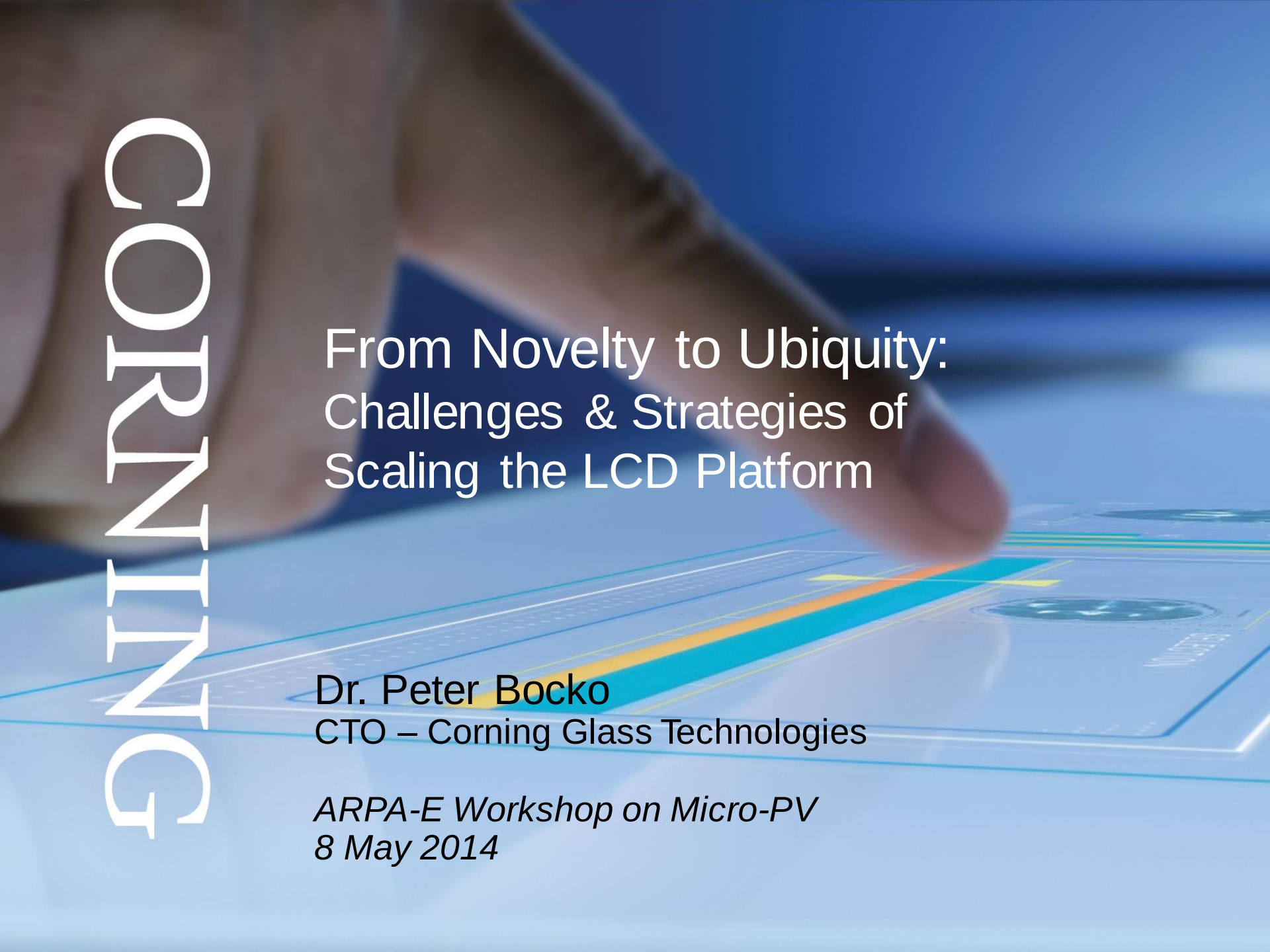


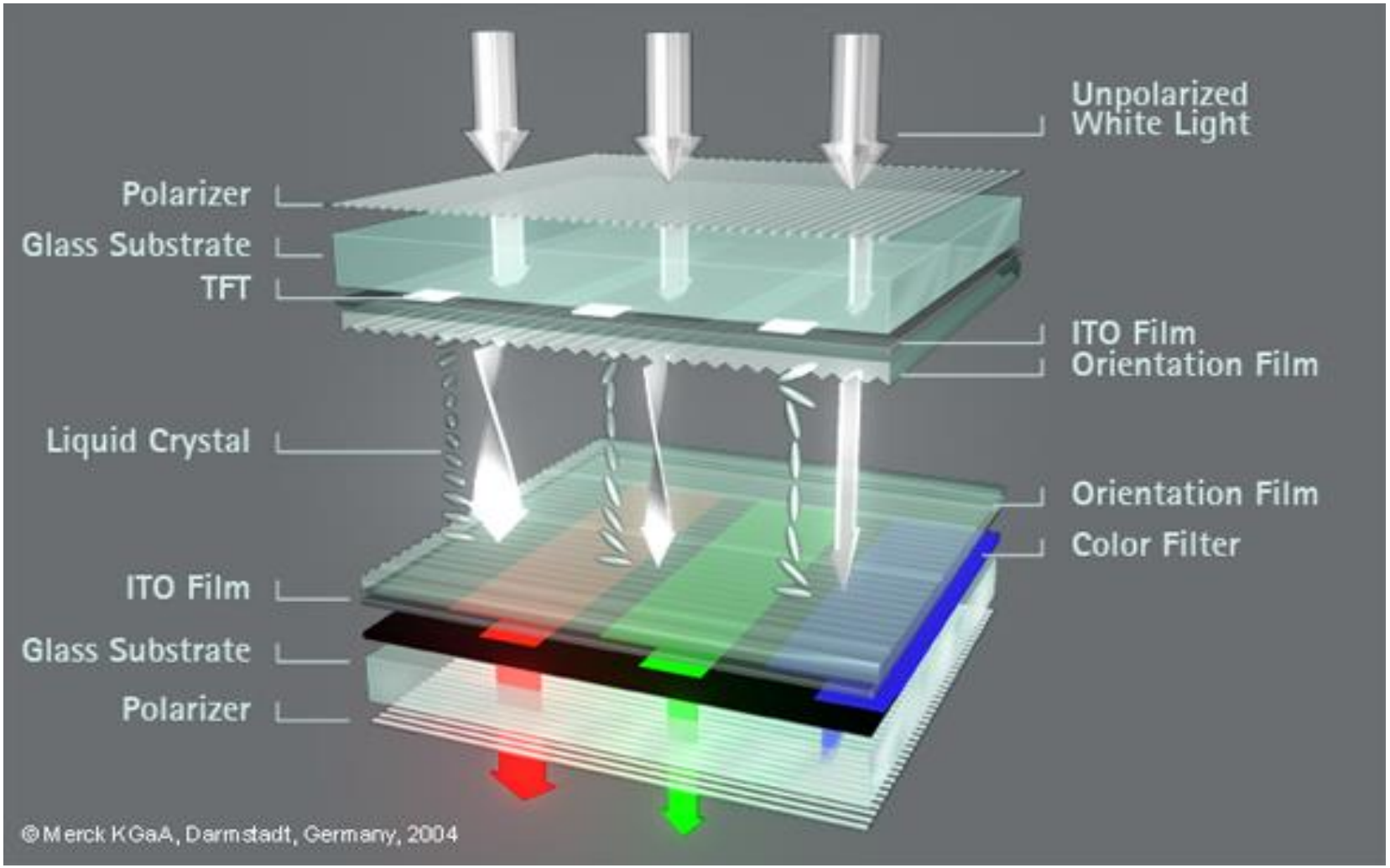
CORNING

From Novelty to Ubiquity:
Challenges & Strategies of Scaling the LCD Platform

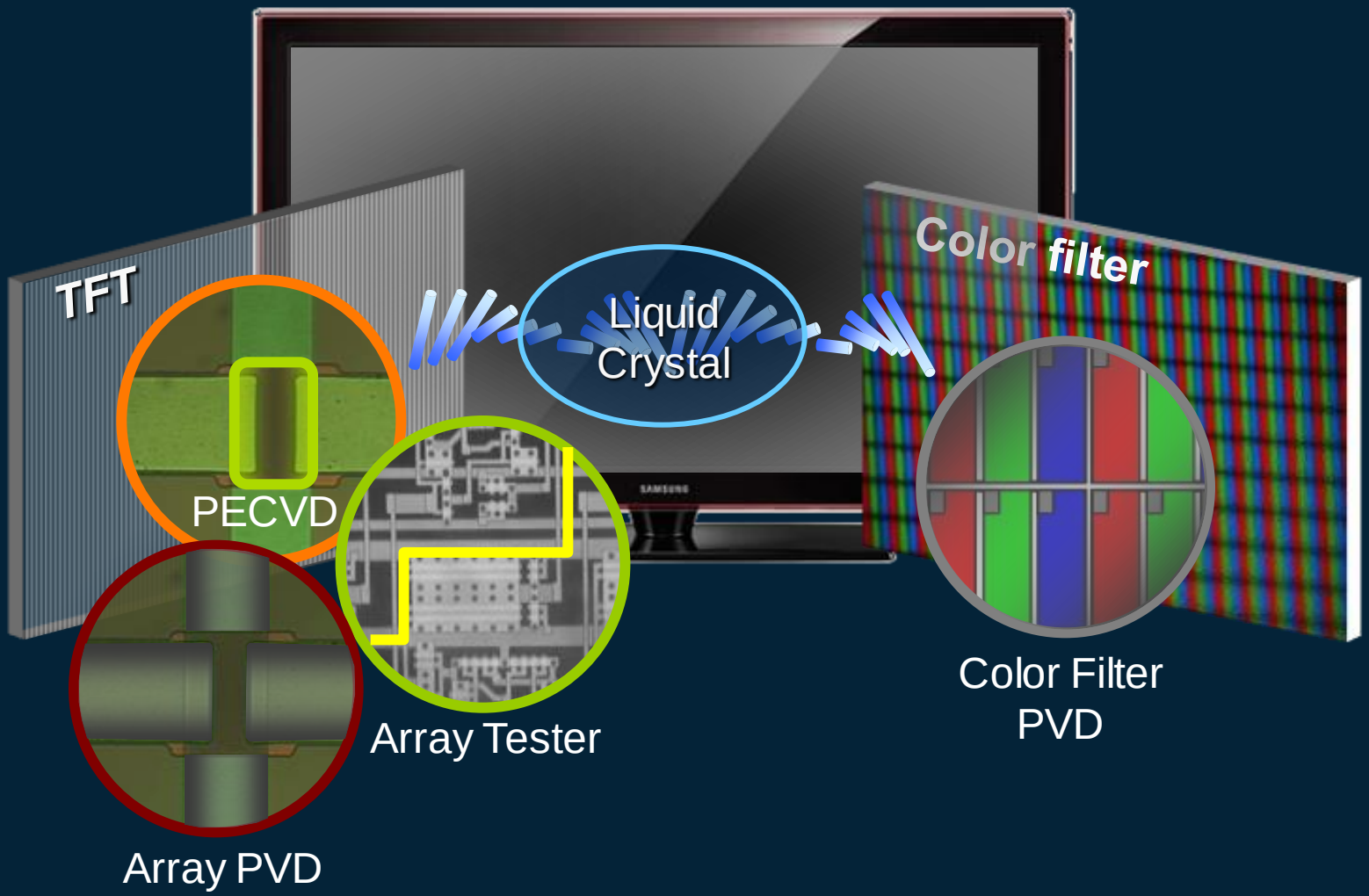
Dr. Peter Bocko
CTO – Corning Glass Technologies

ARPA-E Workshop on Micro-PV
8 May 2014

What is an active matrix LCD? What product did Corning sell?



TFT-LCD Panel Manufacturing



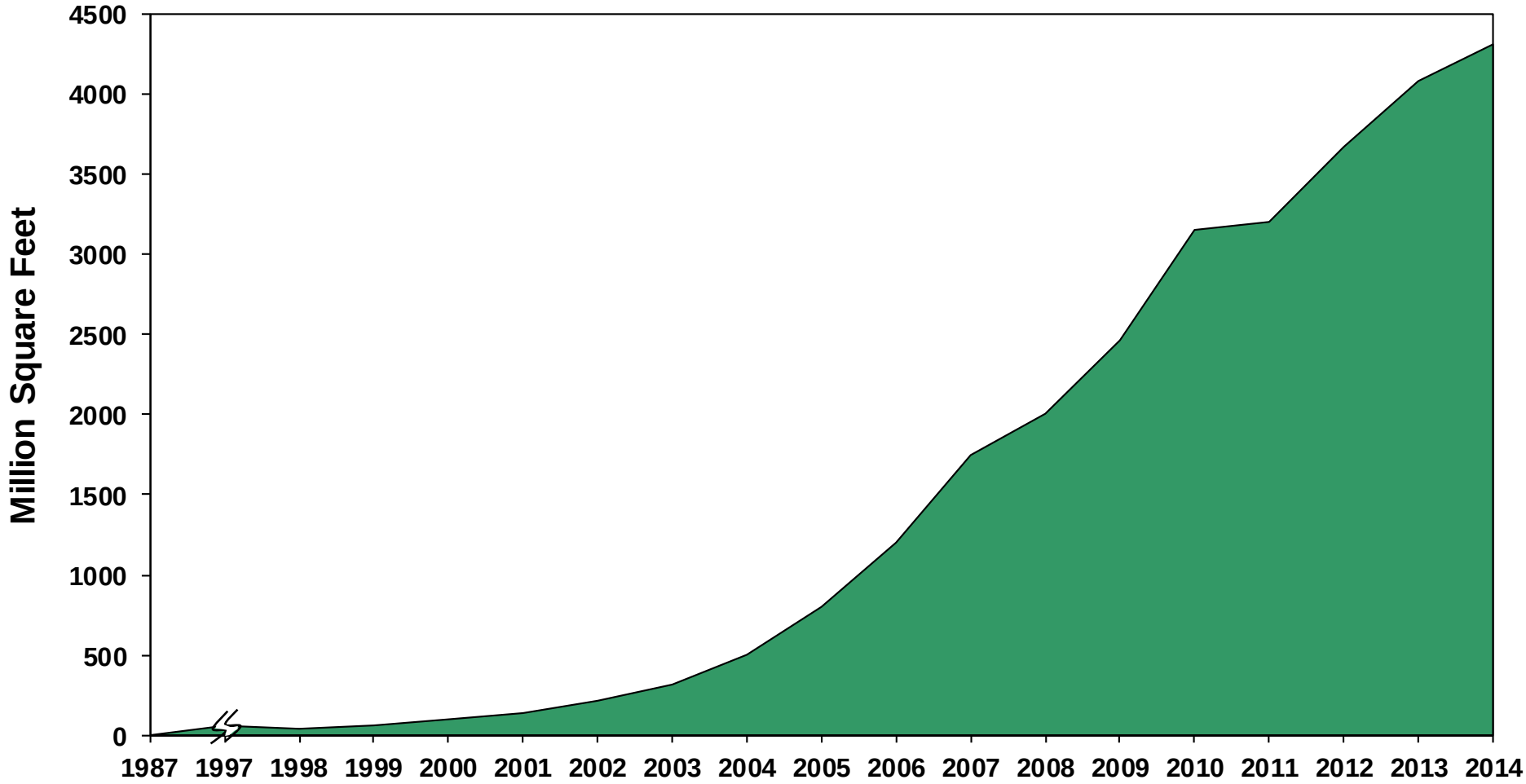
Source: Display Search, Applied Materials

Mid-1980's – First commercial active matrix LCD devices

- Corning supplies substrates for company's first commercial active matrix LCD product
- 3-inch TV made by Matsushita (known commercially as Panasonic) debuts in 1986

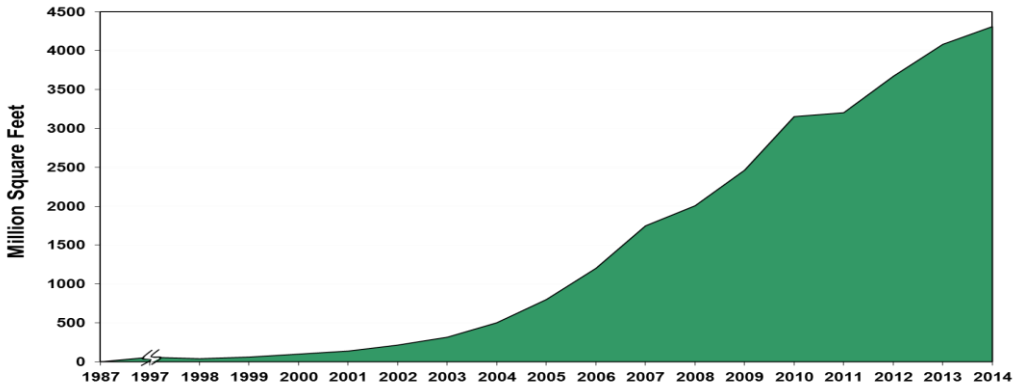
LCDs are ubiquitous today based upon the versatility of the platform

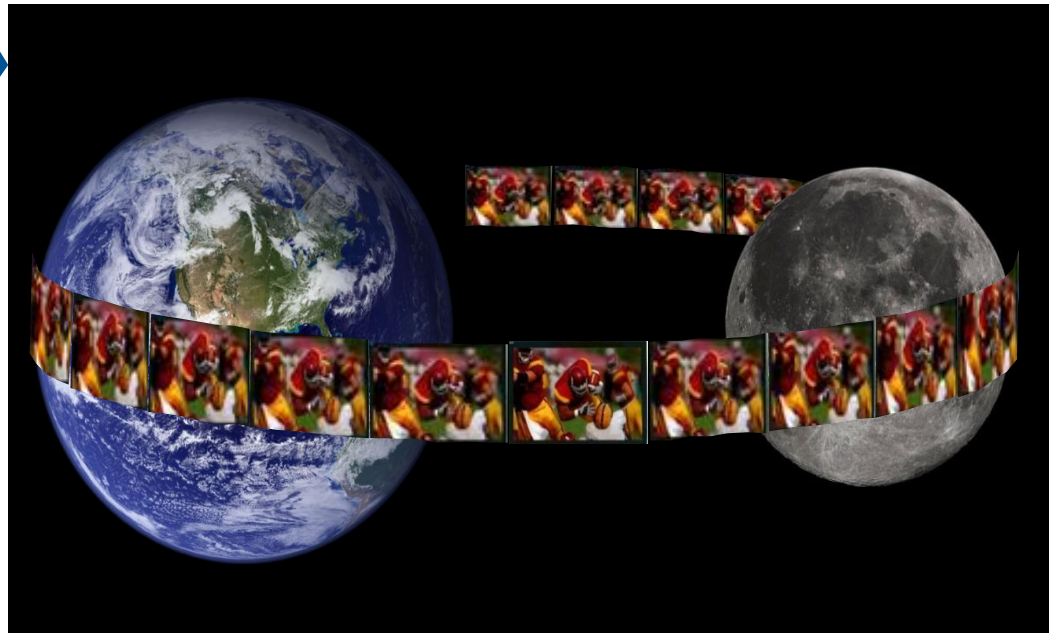
LCD platform success, far from assured in the late 80's, is evidenced by 2013 substrate consumption of over 4 B ft²



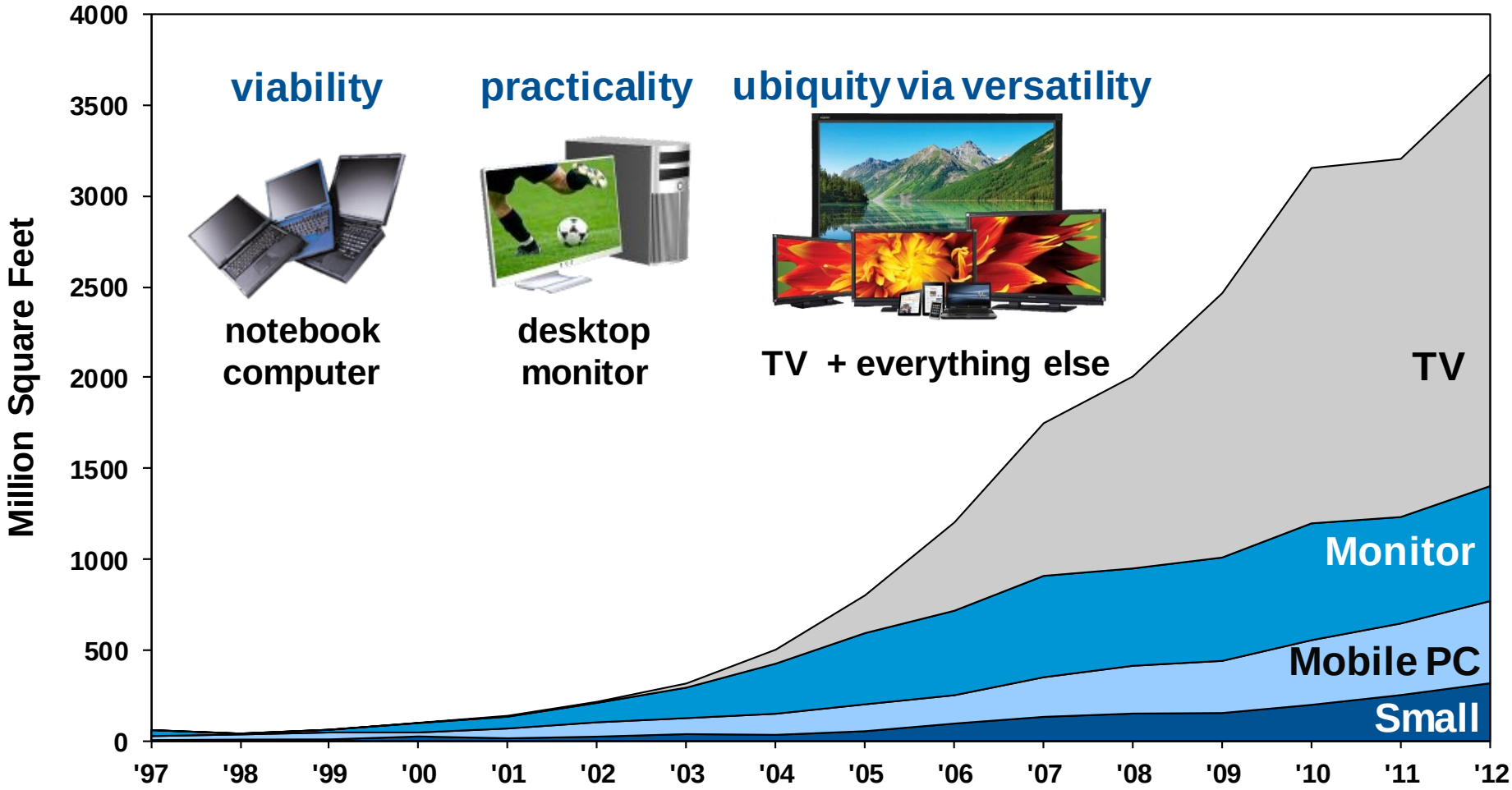
Cumulatively…about 24 billion square feet of high-spec glass have been consumed by the LCD industry since 1987

This is enough glass to create a continuous ring of 100” LCD TVs circling the earth and the moon





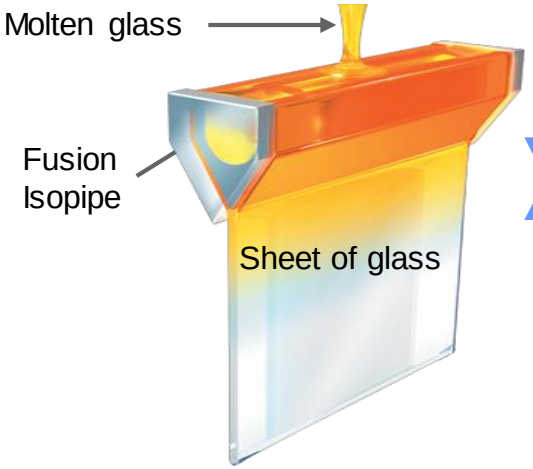
The LCD glass demand developed through three successive waves of application growth

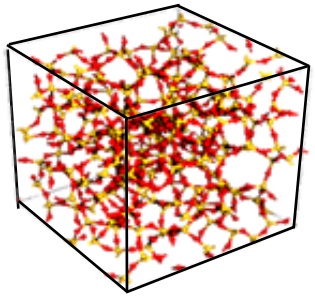


Glass is just one component in the LCD value chain
Our recipe for 20 years of sustained value

Advanced optical melting + fusion sheet forming process

Innovative aluminosilicate glass compositions

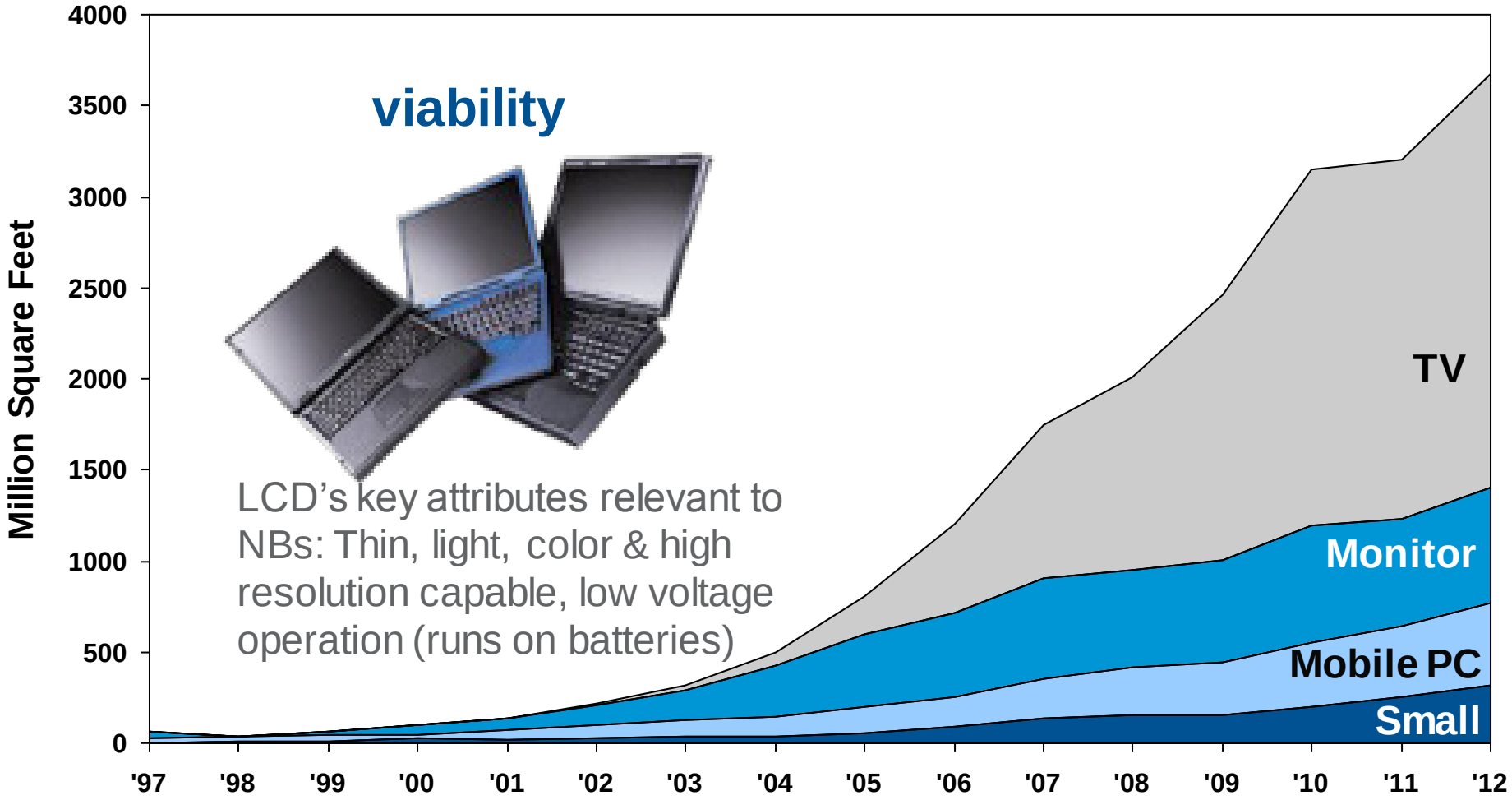




Clean

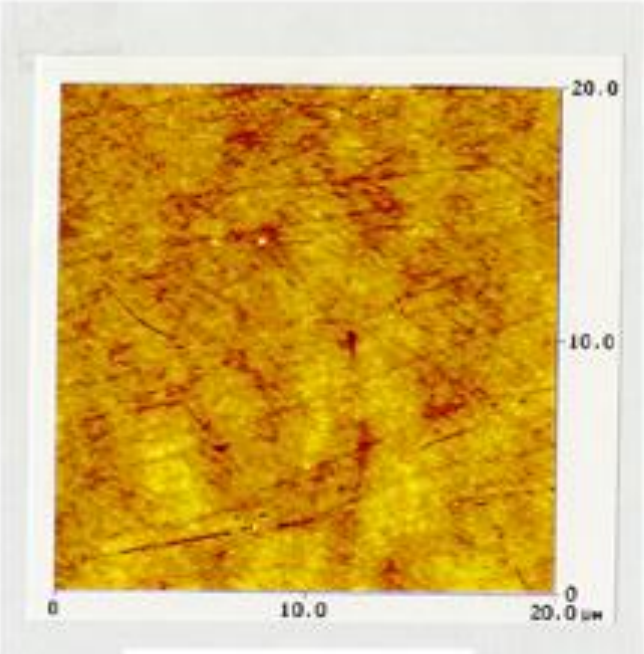
Stable **Flat**

LCD commercialization (approx. '89-'94) proved viability of the LCD platform via the notebook application



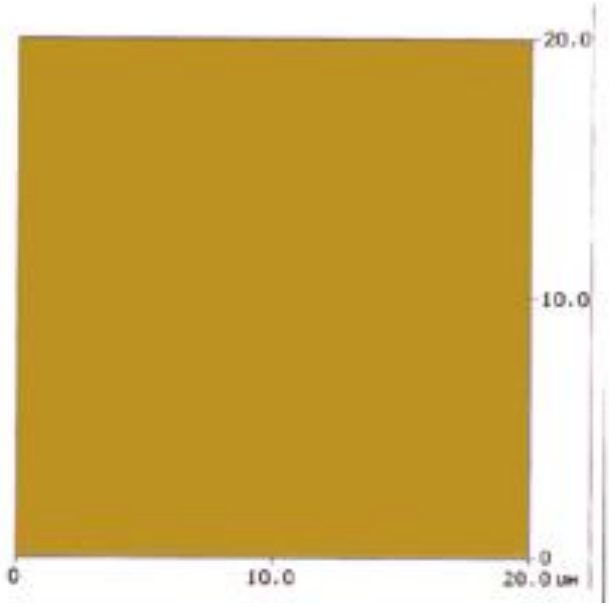
Understanding the core of glass value: What enabled scale was surface

Ground/Polished



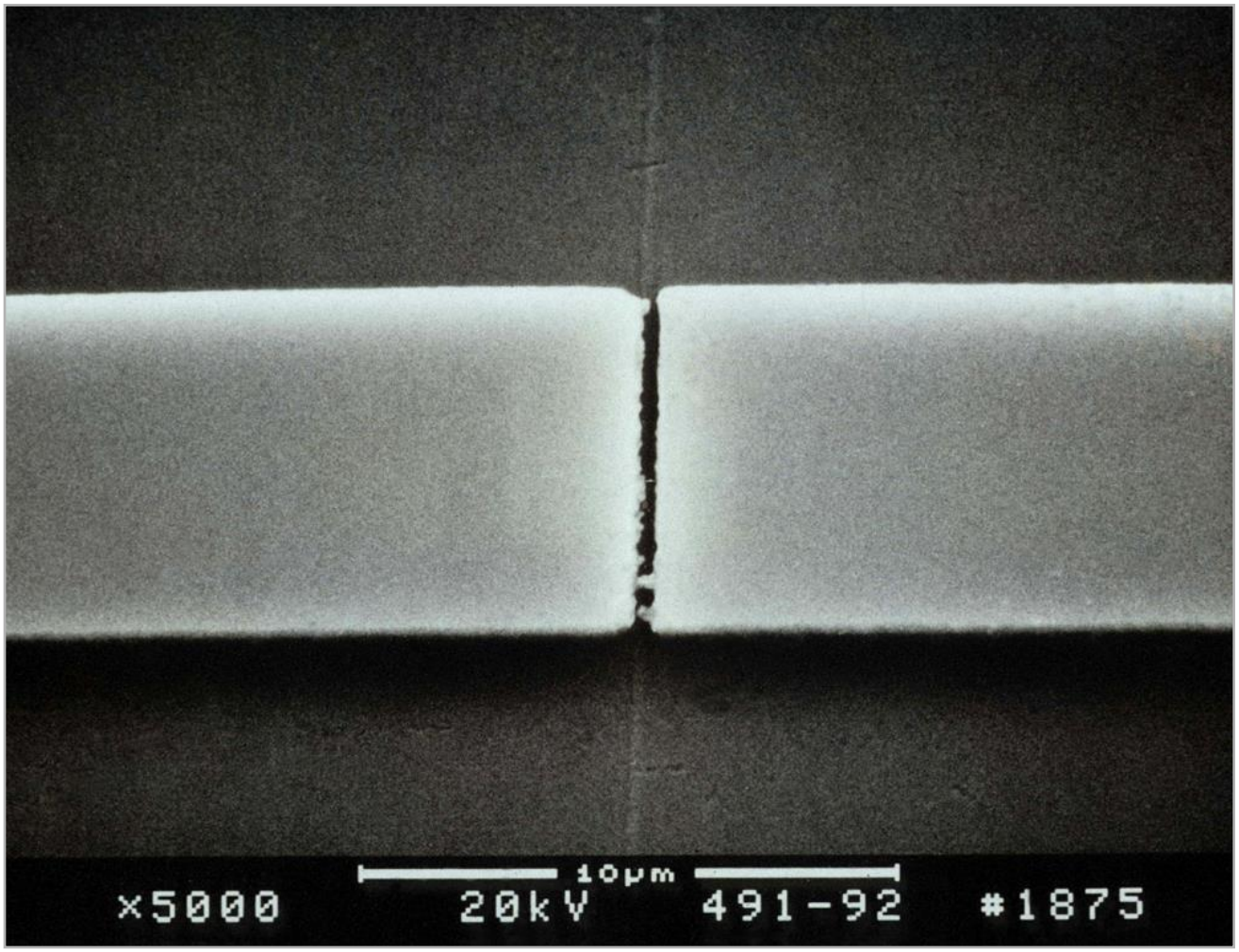
ca. 1997 competitor polished glass

As Formed

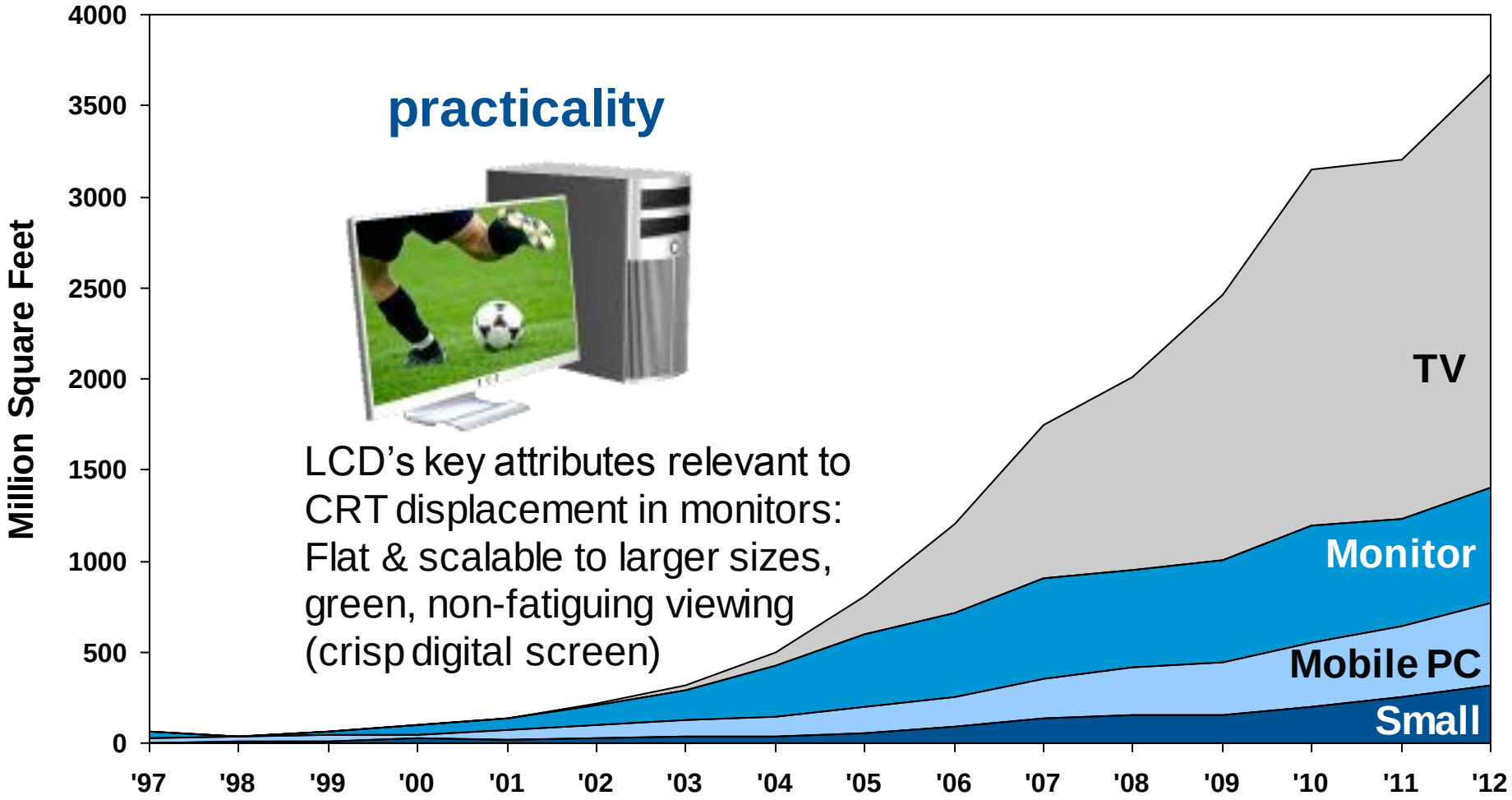


Corning code 7059 non-polish glass

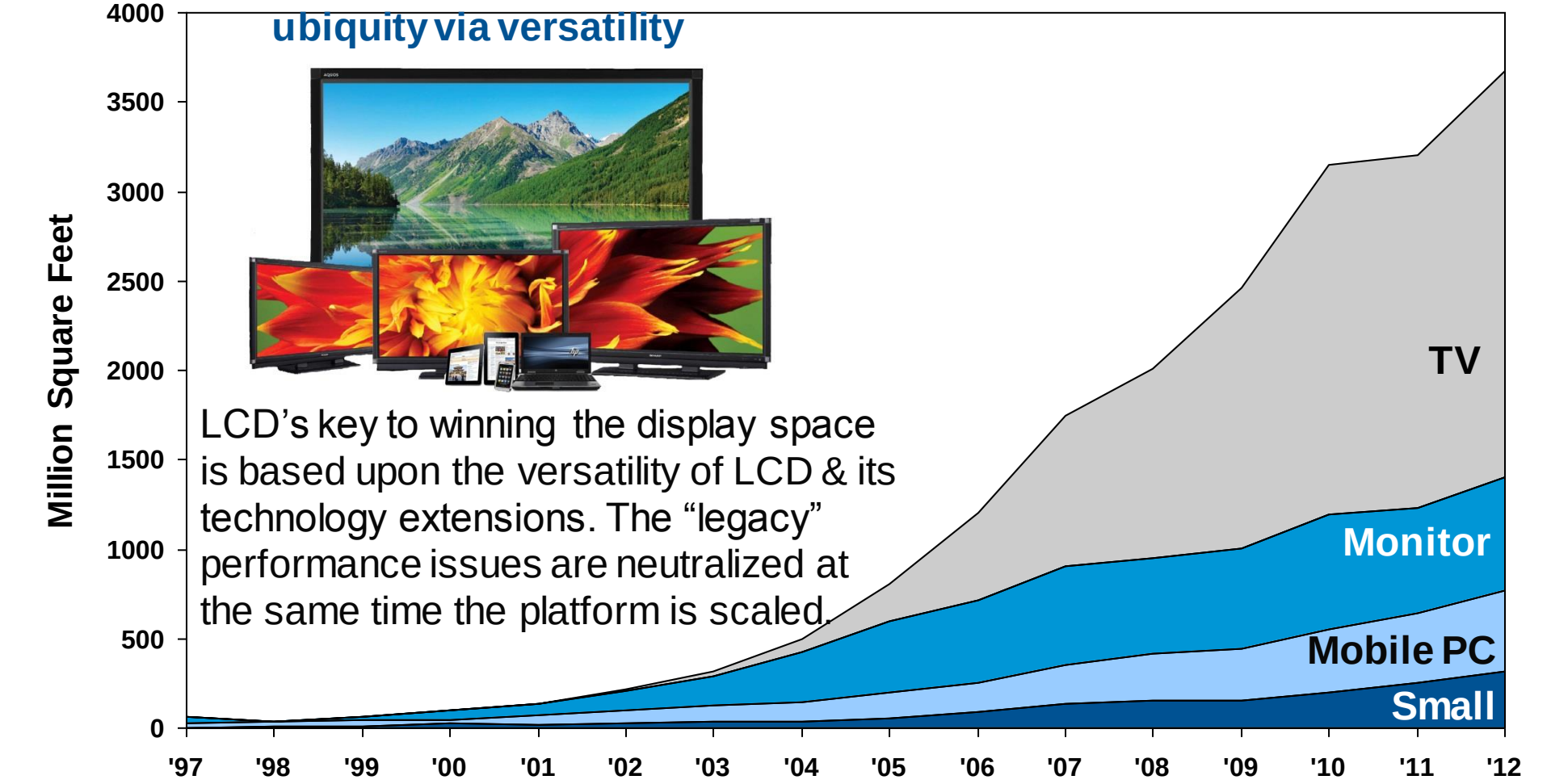
Early learning was that the finest sub-micron scratch can result in yield loss



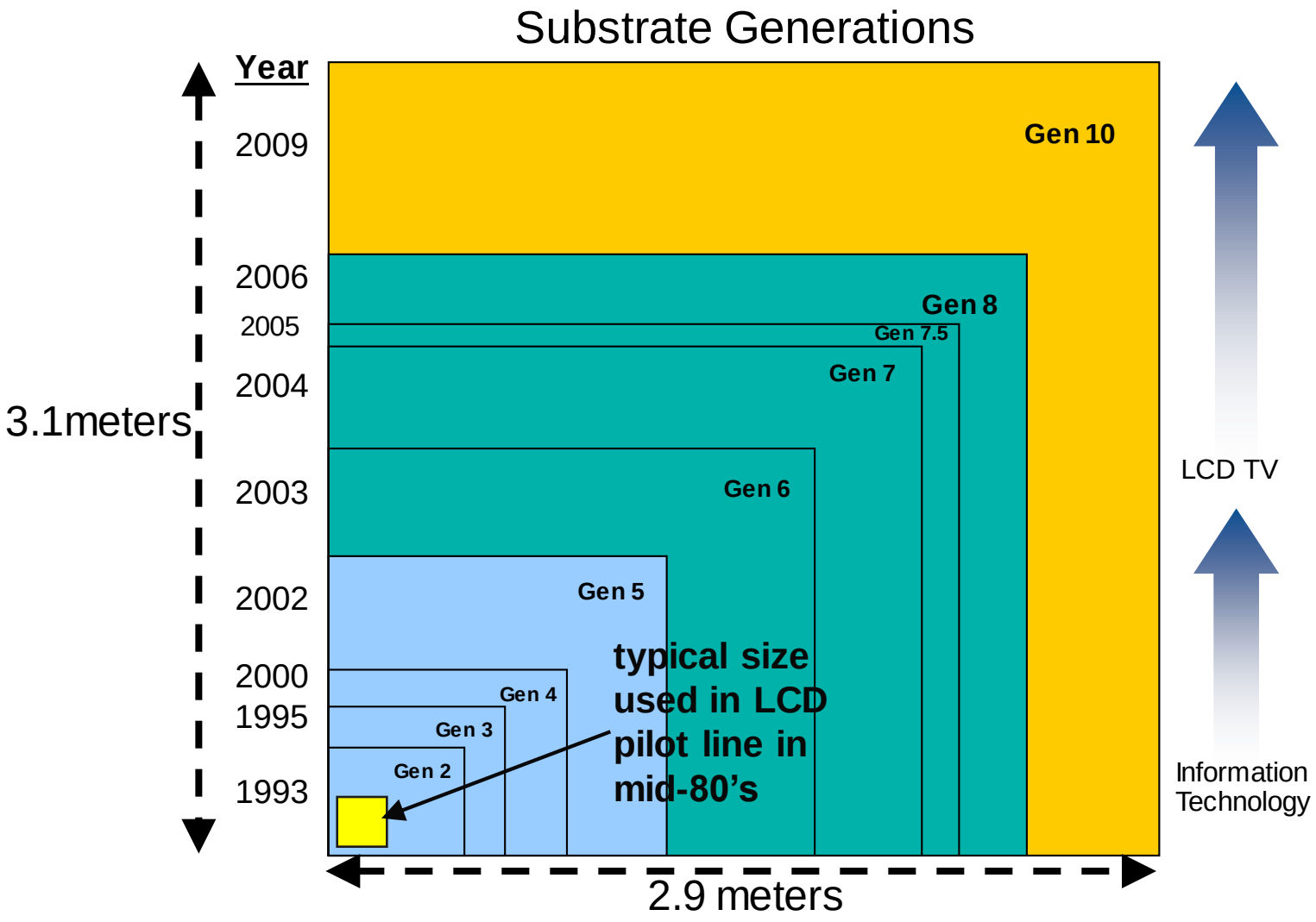
From 1995 – 2002 the LCD proved practicality by displacing CRTs in the computer monitor application



LCD Ubiquity: 2003 - Present



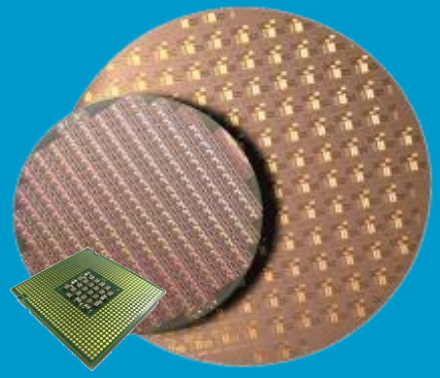
Scaling the LCD substrate area: 100X



Exponential Growth Industries

Where Technology enables Demand

① IC



cost per transistor

1980	1994
3µm	0.35µm
~$330/Mb	~$3/Mb
~3X10^{12} bits	~7X10^{15} bits

Above data for DRAM

Source: SIA, In-Stat, IC Insights

② LCD

cost per area

1999	2008
0.62 x 0.75m	~3 x 3m
$10,000/m^2	$1,190/m^2
1 million m^2	84 million m^2

Source: Display Search, Nikkei BP, Applied Materials

③ SOLAR

cost per watt

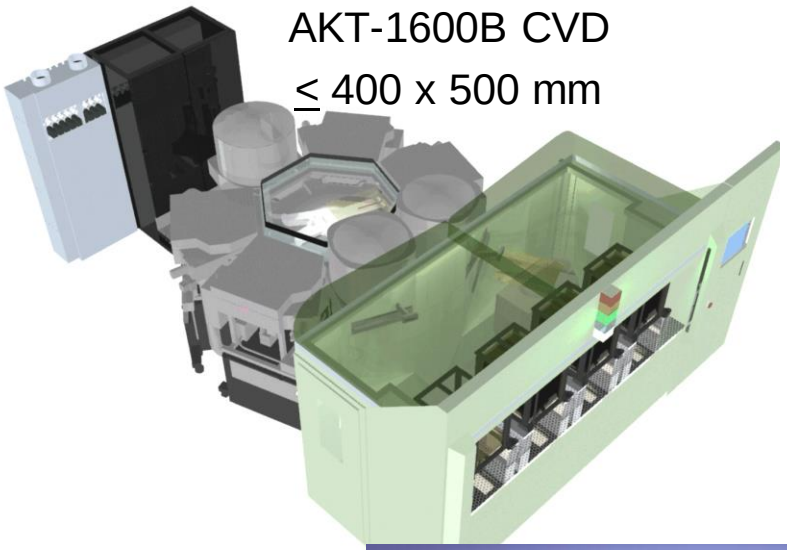
2008	?
c-Si	c-Si/TF/Other
~$4/Wp module	$1-2/Wp module
~5GW	>50GW

Source: Applied Materials

AKT PECVD System Family for Flat Panel Display Manufacturing

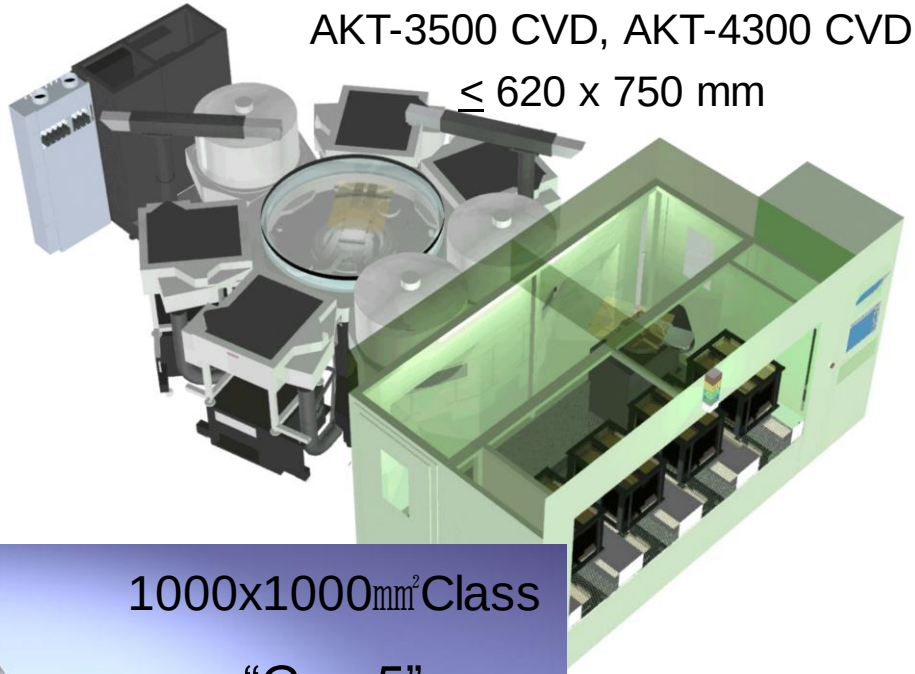
AKT-1600B CVD

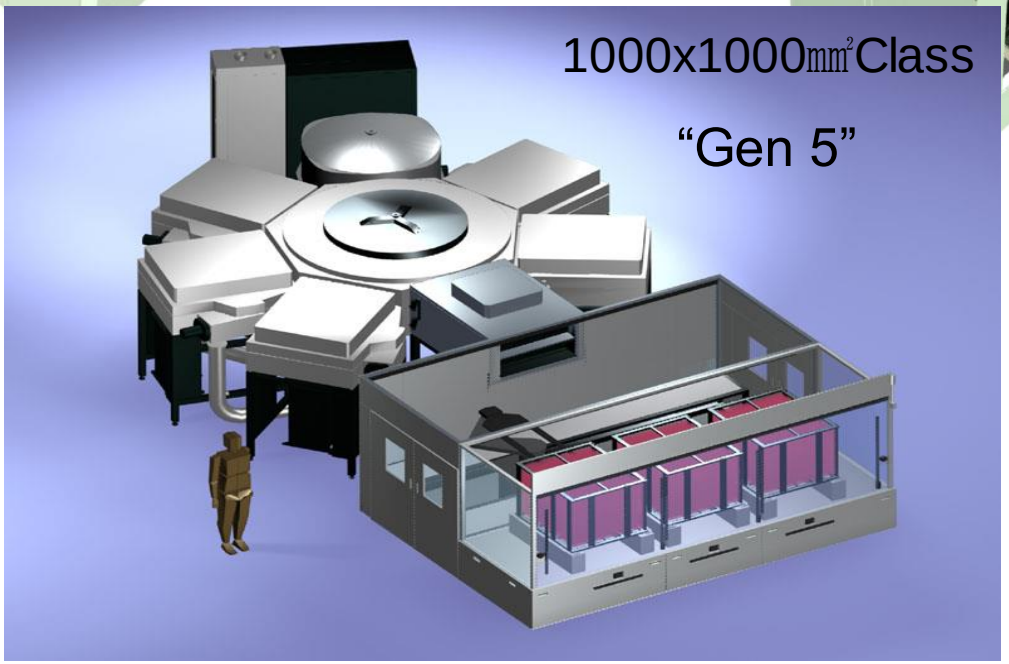
≤ 400 x 500 mm



AKT-3500 CVD, AKT-4300 CVD

≤ 620 x 750 mm

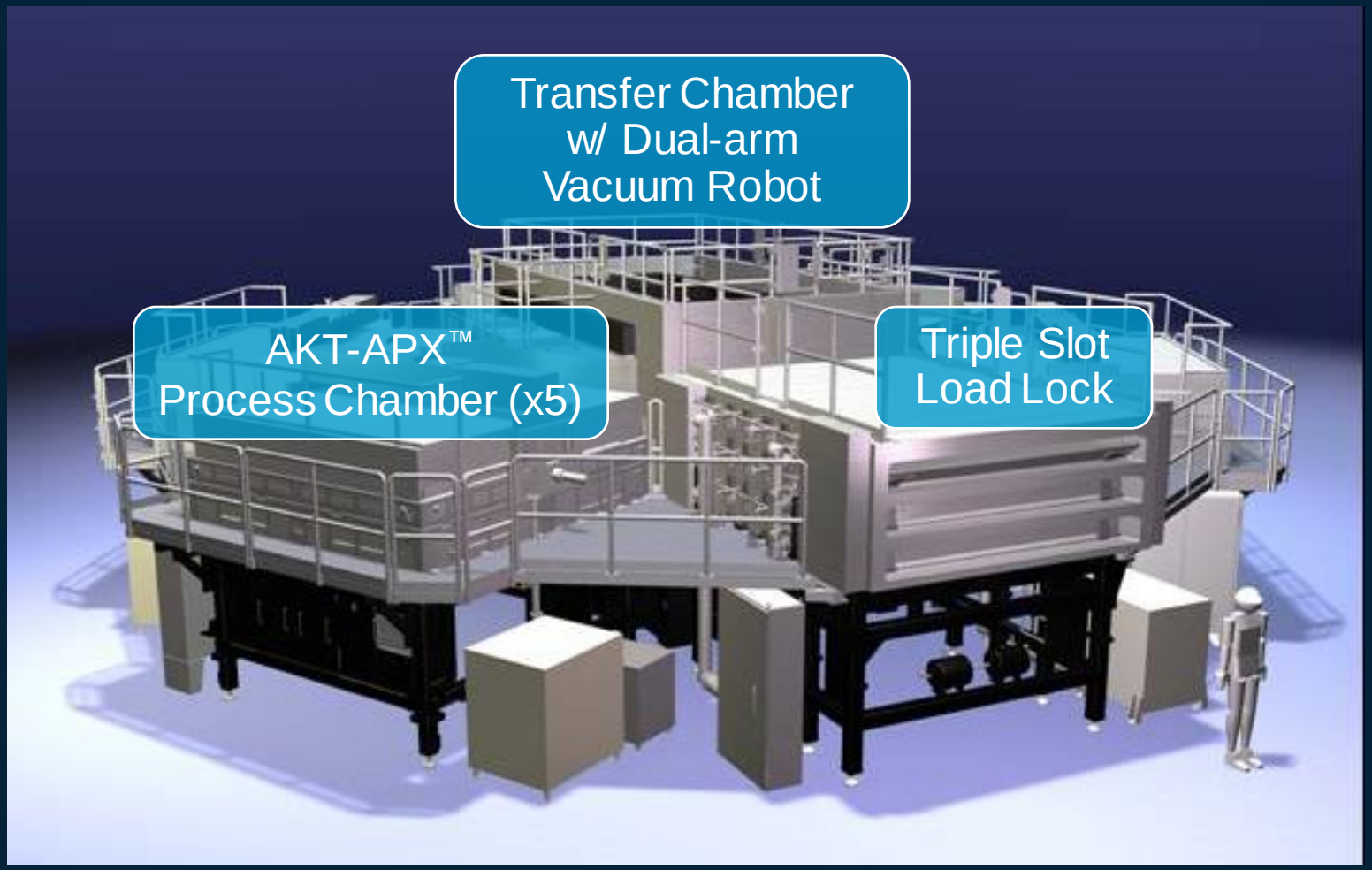




Envisioning the Future

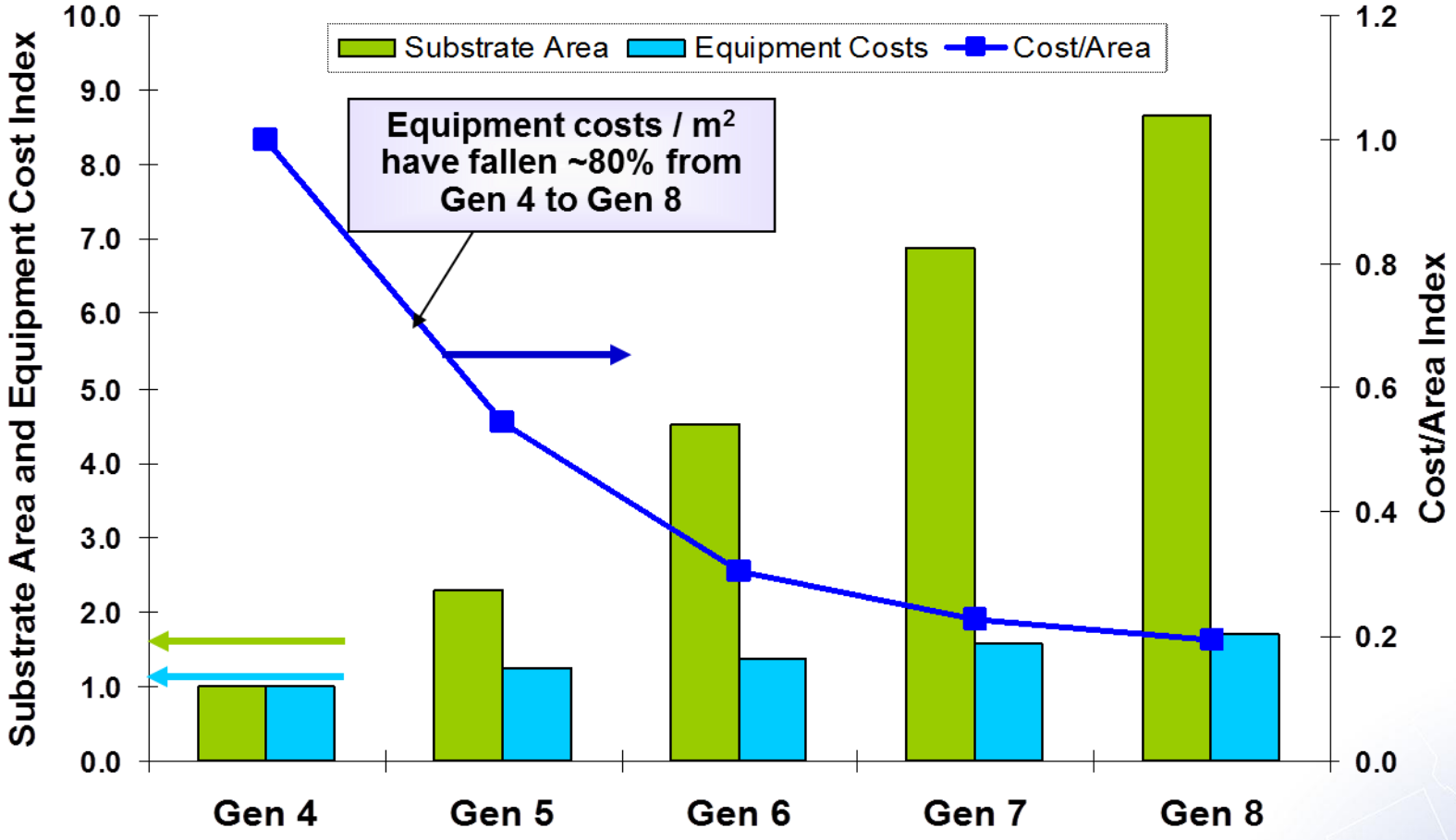
AKT

AKT-90K PECVD (Gen 10) System Overview



Foot print: ~14m x 14m | Weight: 273 metric tons

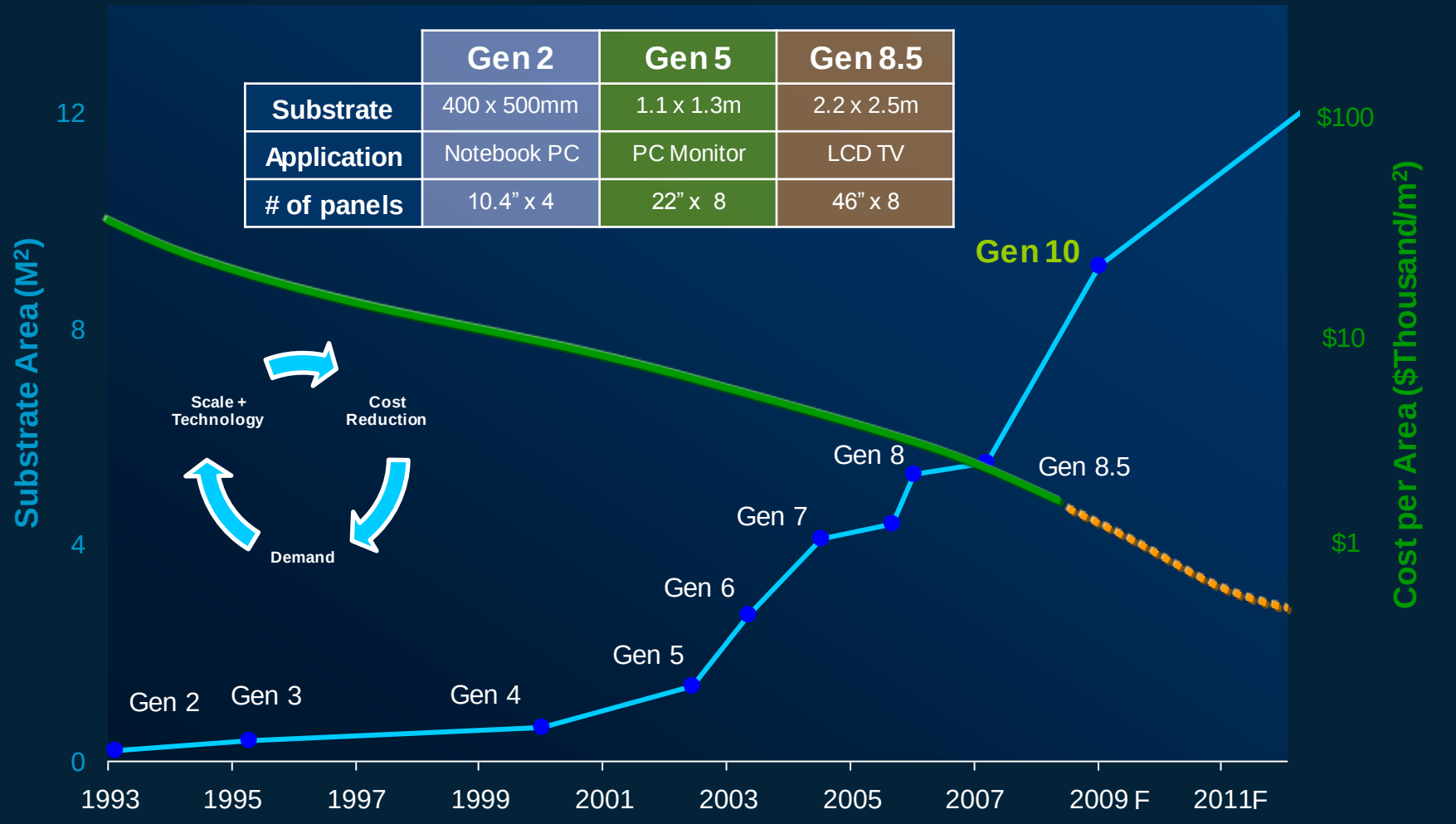
Equipment Cost Per Glass Area ($/m²)



Note: Equipment costs include equipment depreciation and gas costs

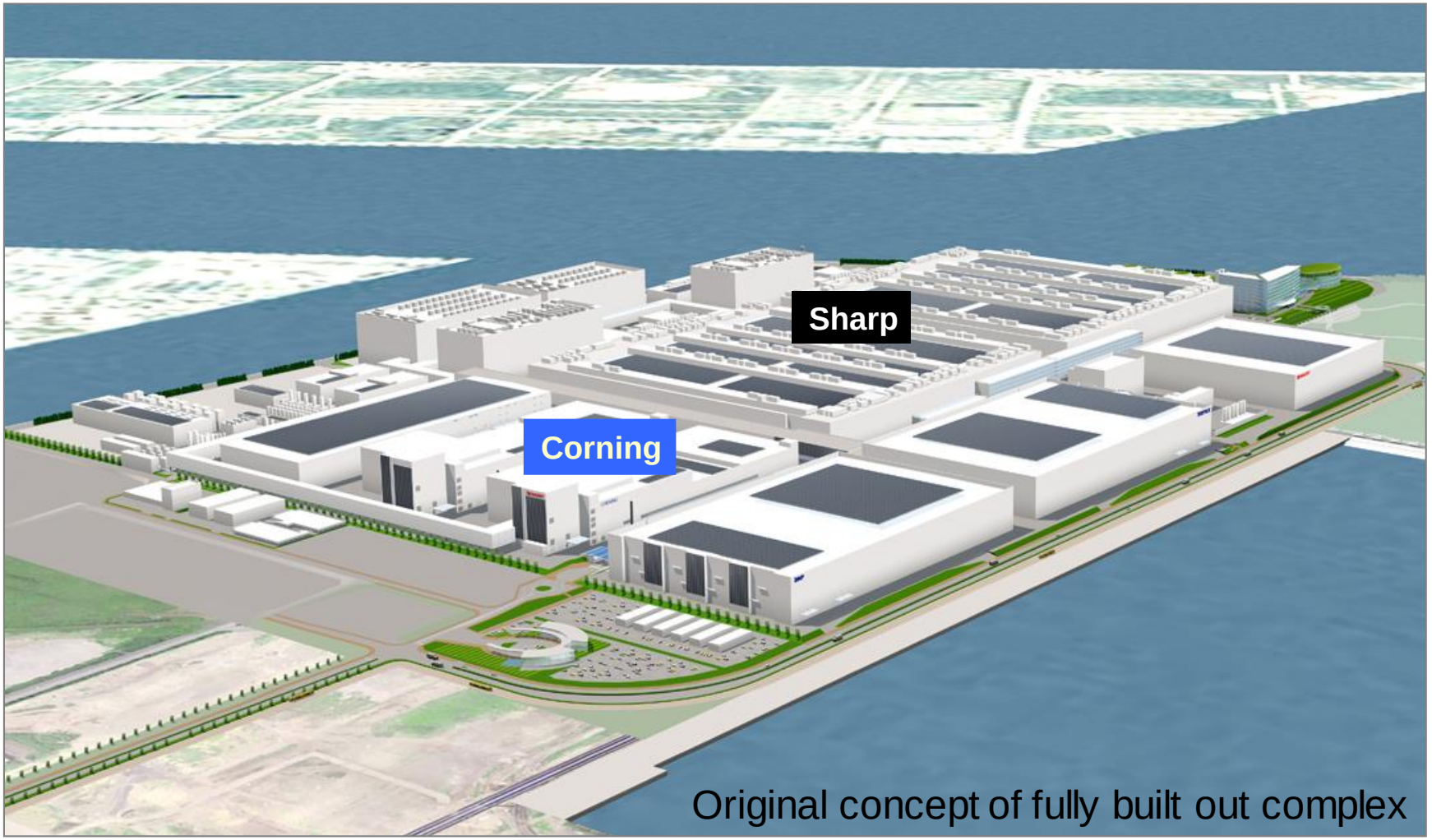
Dramatic Improvement with Larger Substrates

Glass Size Migration – Driving Cost Reduction



Generation Scaling and Cost Reduction Key to Growth

The terminal Gen Platform: Sharp's Gen 10 "Green Front Sakai" brought LCD to 3 meter scale

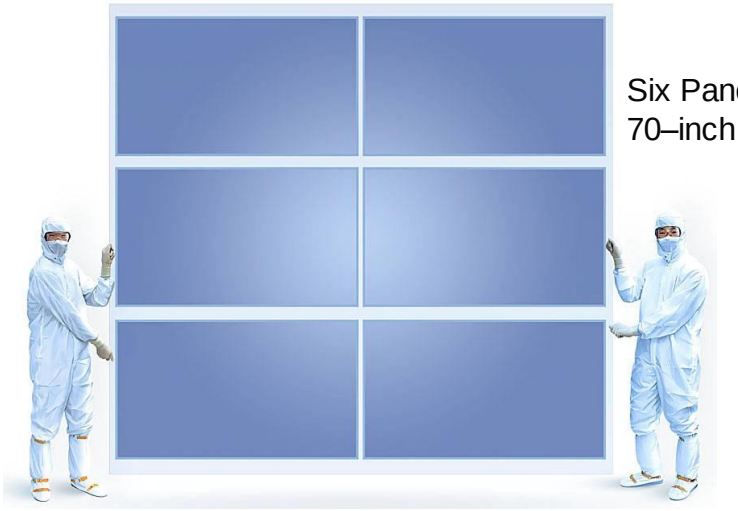


Rendering is of Sharp's Manufacturing Complex for the 21st Century, located in Sakai City, Japan.

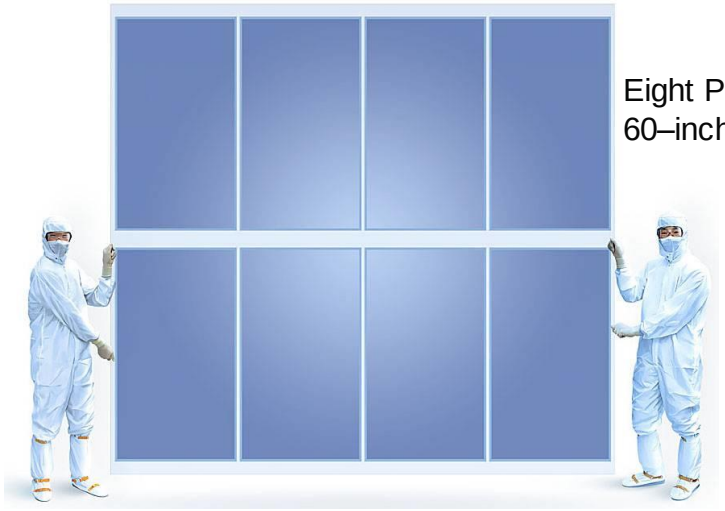
The terminal Gen Platform: Sharp's Gen 10 "Green Front Sakai"

- Facility is the first of its kind in the display industry
  - Corning is on of 19 companies on site: mutual benefits in logistics, inventory and quality
- Complex is 314 acres, the equivalent of 240 football fields
- Environmentally advanced production
- Panel production capacity:
  - At full capacity, capable of over 1 million 40" LCD panels/month

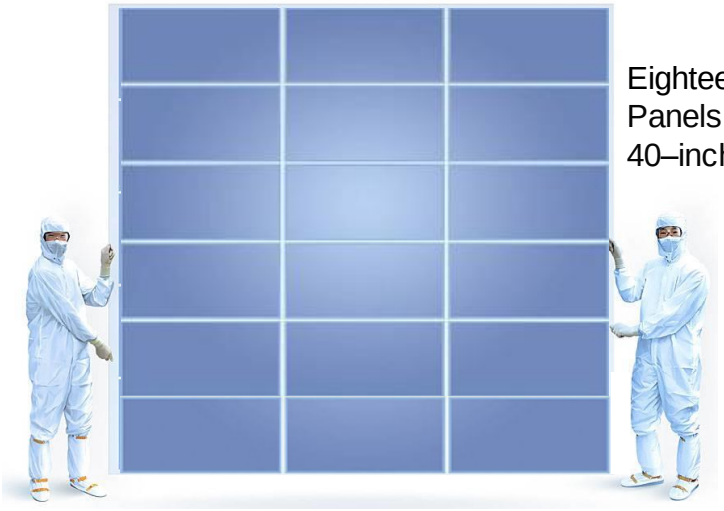
Gen 10 efficiently produces wide range of panel sizes



Six Panels
70–inch class



Eight Panels
60–inch class



Eighteen Panels
40–inch class

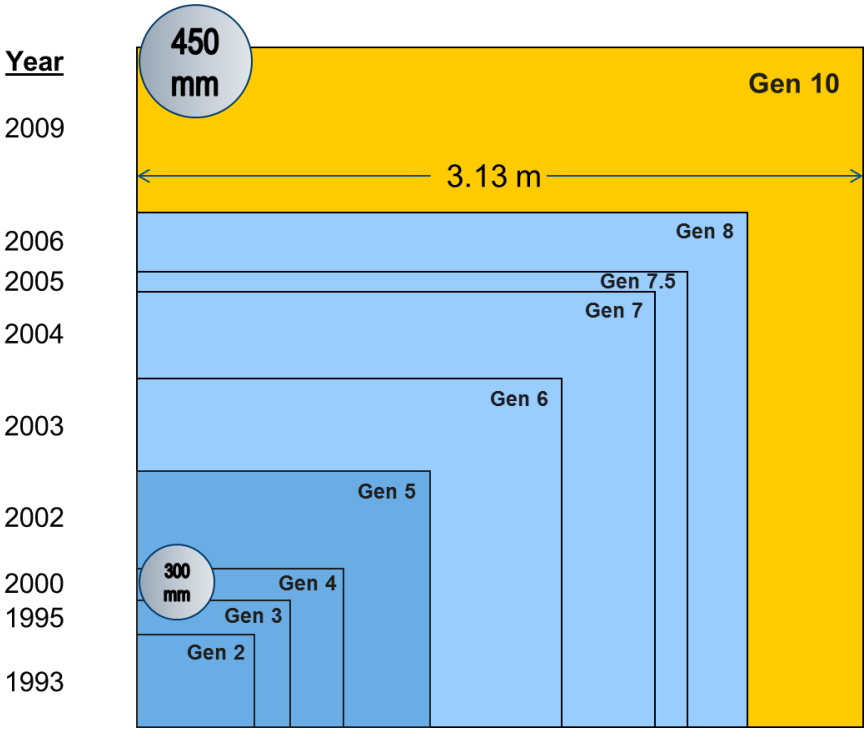
Comparison of Panelization: Gen 10 vs. Gen 8

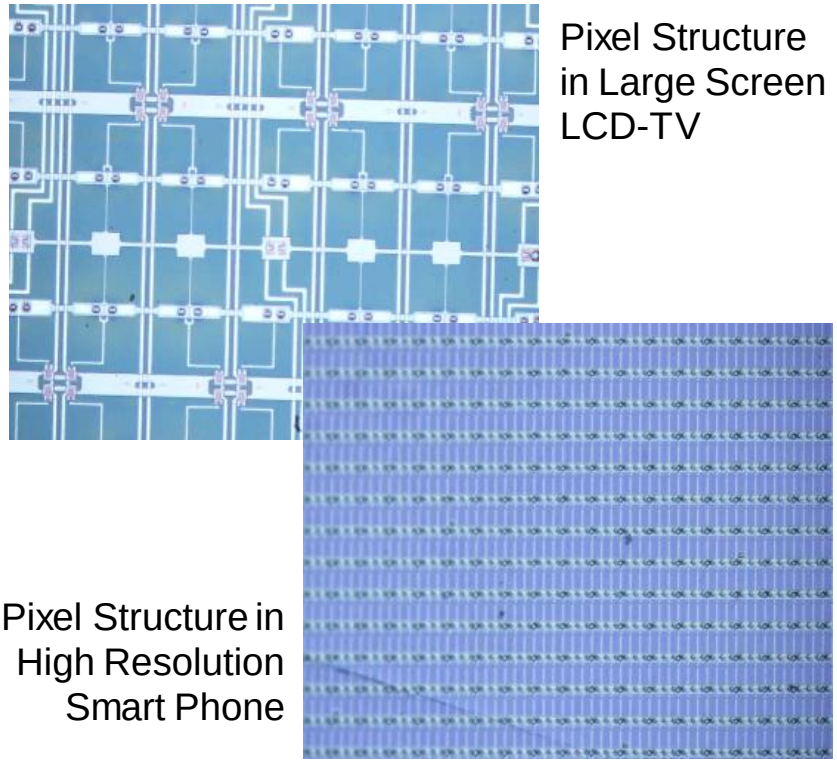
Panel Size	Gen 10	Gen 8
	Panel Number	Panel Number
70–inch class	6	2
60–inch class	8	3
40–inch class	18	8

Corning moves Gen 10 glass directly into Sharp's process

- Sharp's inter-building transport system moves Gen 10 substrates directly to production floor, eliminating traditional delivery systems. Previously, transportation infrastructure has limited glass substrate size

Is there a Moore's Law for Display? Kind of…





Pixel Structure in Large Screen LCD-TV

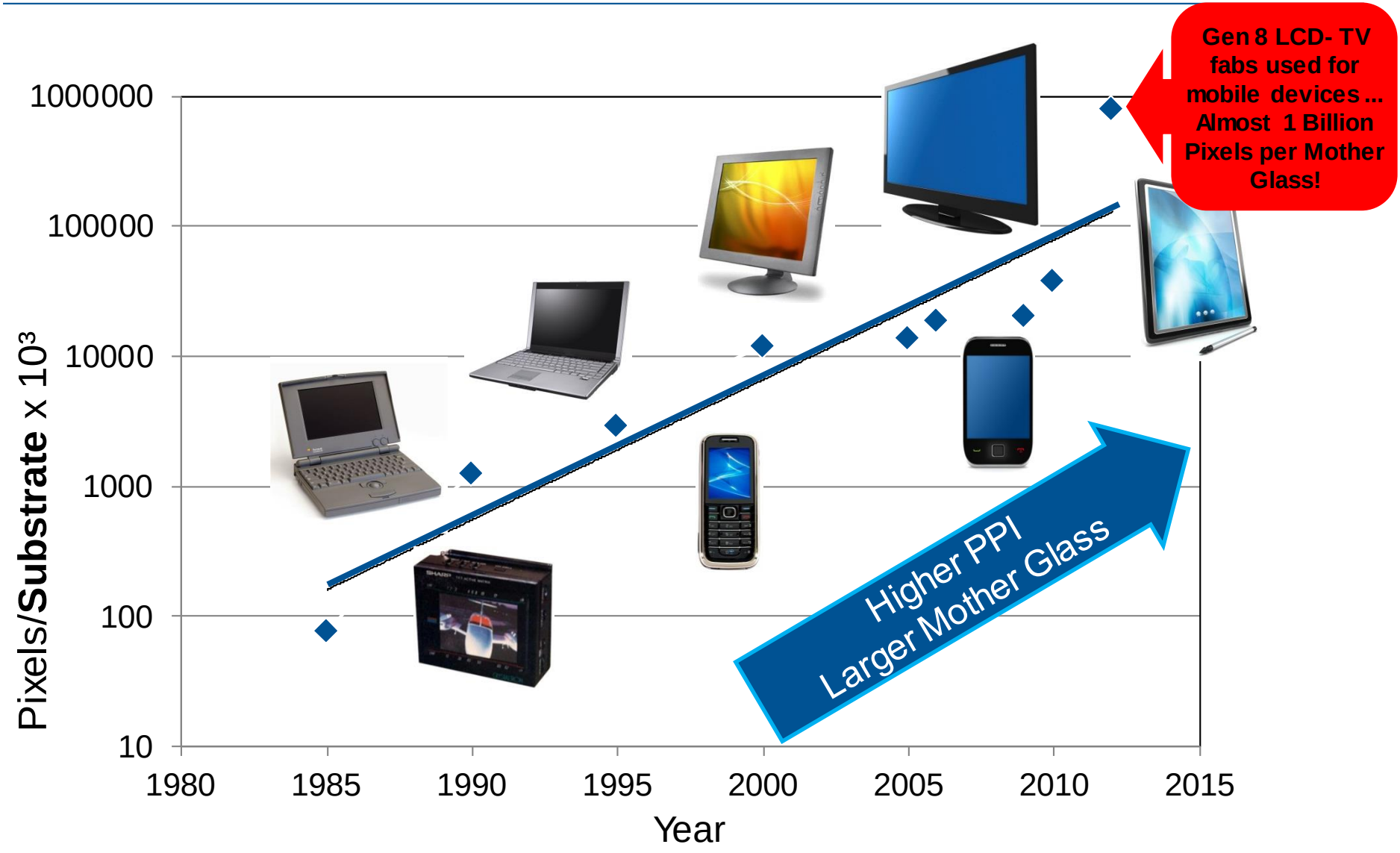
Pixel Structure in High Resolution Smart Phone

Large mother glass used for multiplicity of display panels

+

Higher resolution in small & intermediate mobile devices

Resolution trend: Moore's Law for LCD manufacture



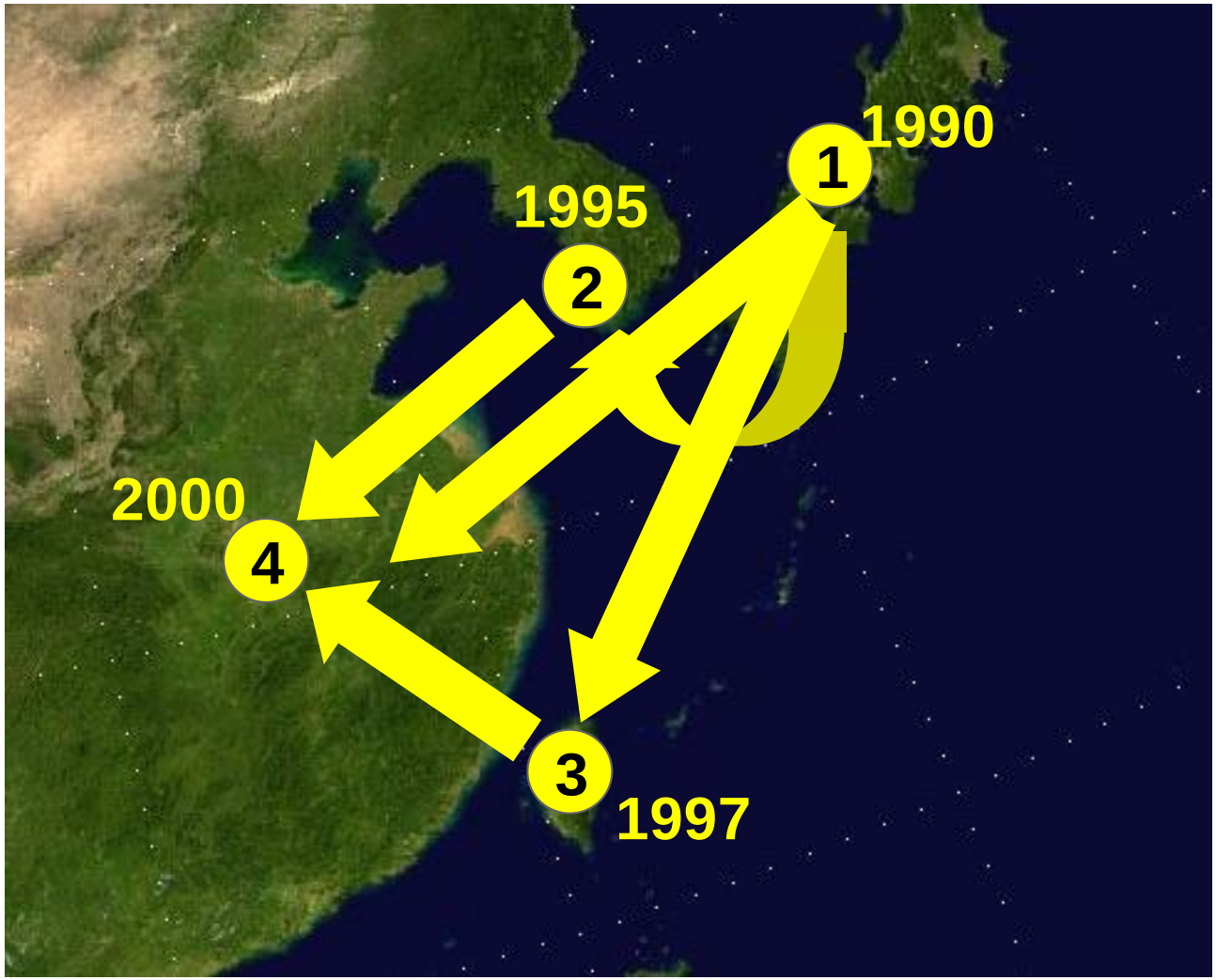
This brings us up to the present…

LCD platform is continuing to grow…abundant opportunities for extending display functionality & performance…so the scaling of the LCD platform is a great success story, right?

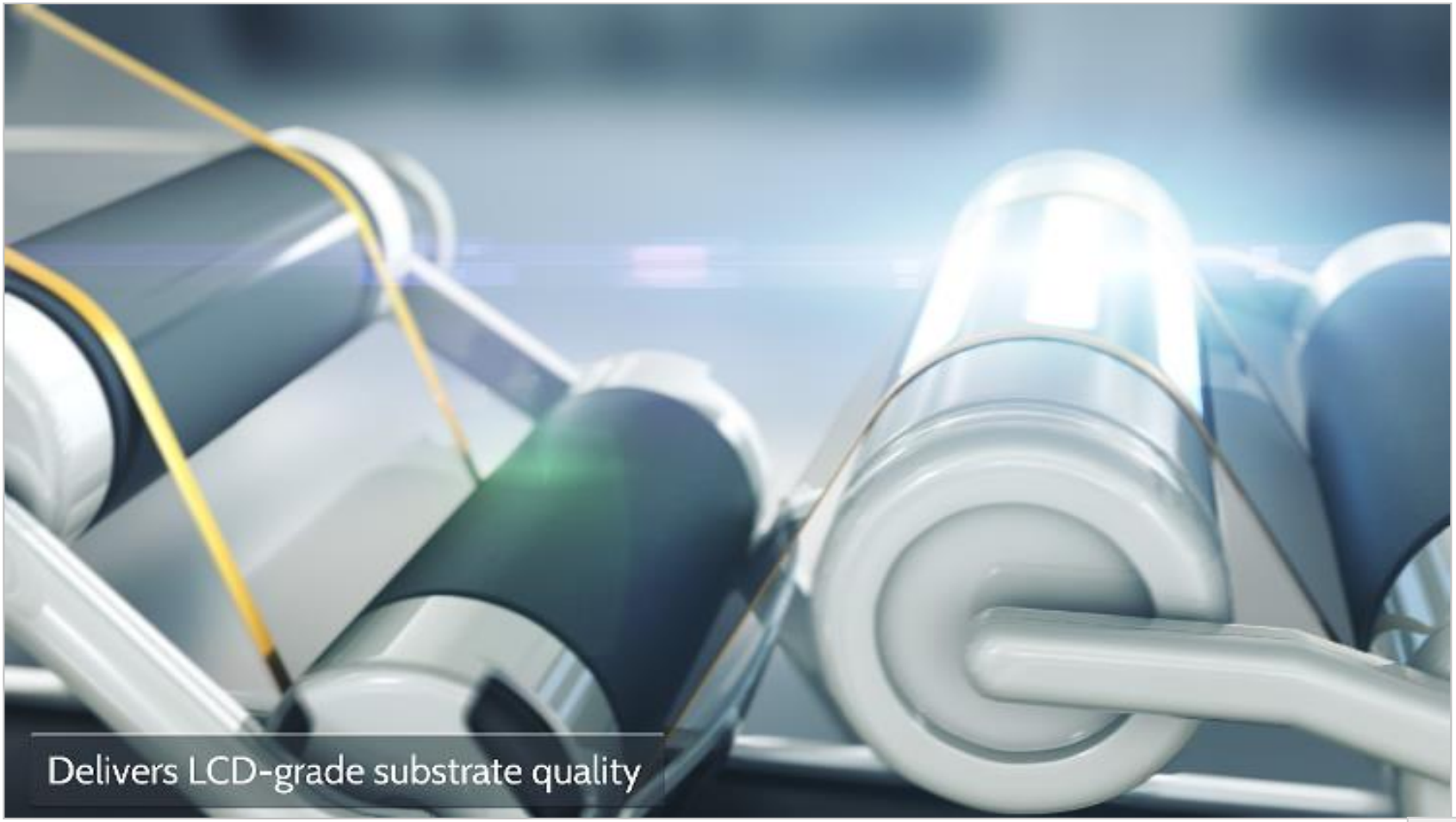
WRONG! (for the participants…great for the consumer)

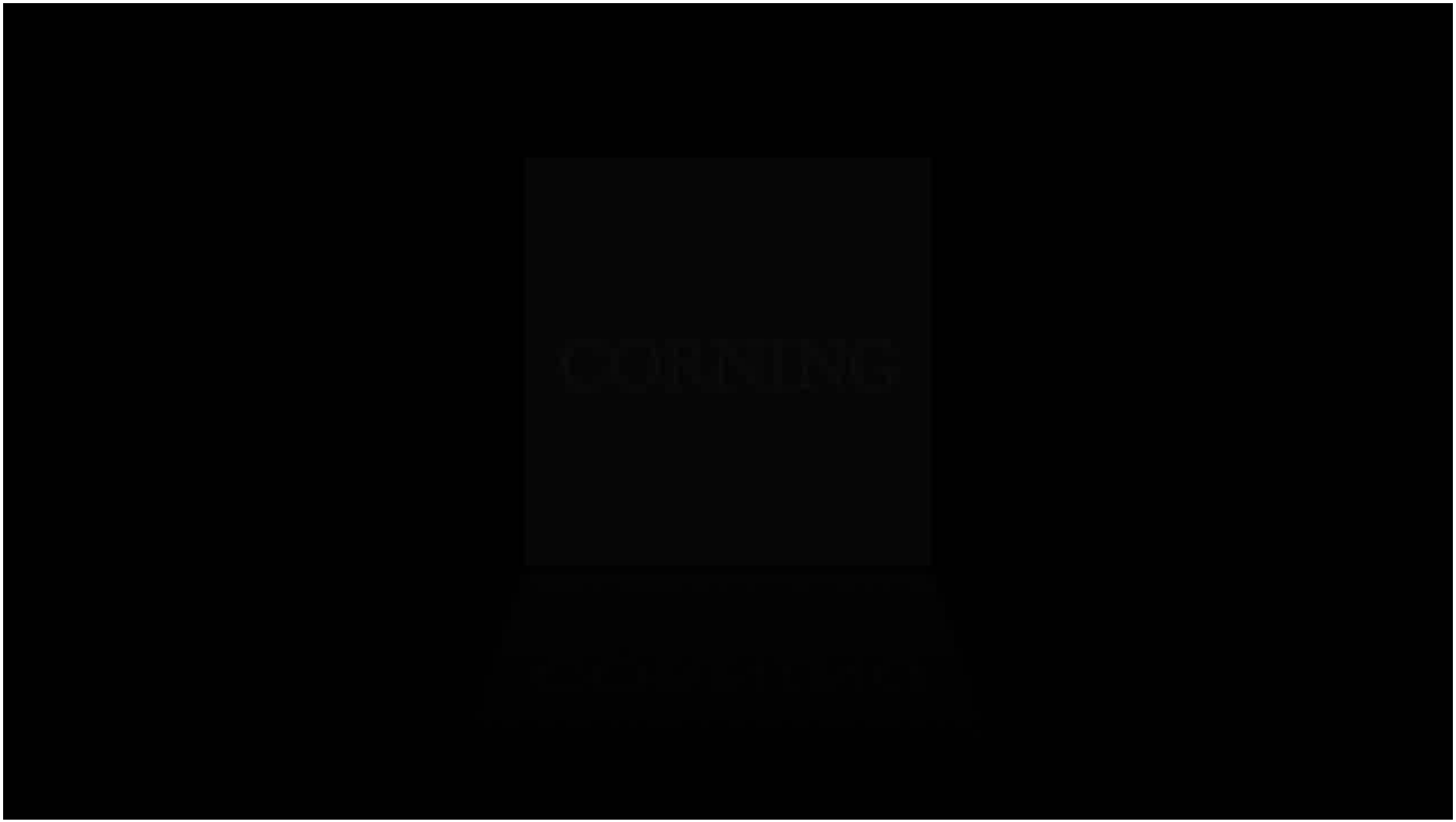
- **LCD platform looks like a 25 year suicide pack for display manufacturers characterized by hyper-competition, over investment, periodic non-profitability but requiring sustained investment for product differentiation with poor return.**
- **The glass manufacturer remains the last material component supplier standing in terms of sustained value capture…but the pressure is ratcheted up continually.**

One of the negative aspects of the economics of scaling LCD has been nationalism



Flexible glass is an enabling technology that supports key trends in display devices & future breakthroughs



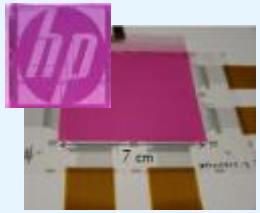


Thin and flexible glass substrates for ultra-slim displays with promise for ultra-low-cost manufacture

- Corning® Willow® Glass is thin enough to be flexible while retaining its superior glass attributes
- Combines inherent benefits of glass with a mechanically bendable form factor, enabling continuous and cost-efficient processing
- Enables thinner, lighter, and potentially conformable electronic devices that deliver high performance at a lower cost
- Eventually, displays will be printed on a flexible web…but years of development are required to make this practical.

Flexible glass applications roadmap – optimistically viewed in 2011 – delayed largely by lack of ecosystem

Lab-scale device demos



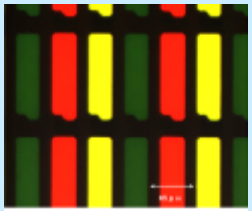
HP Oxide TFTs

WMU / CAMM Organic PV

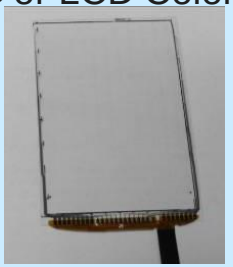
ITRI-DTC Ch-LC display

University of Stuttgart TFT-LCD

Initial commercial products



OLED or LCD Color Filter



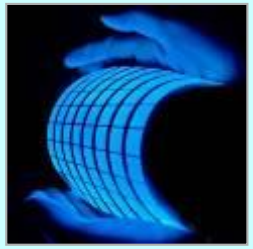
ProCap Touch Sensor

Flexible CIGS PV panels

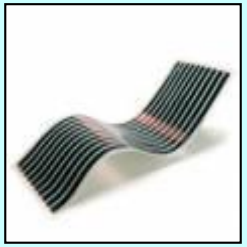
Next-generation technologies

Flexible display

E-Paper



OLED lighting



Organic PV

Roll-to-roll displays

2010 2011 2012 2013 2014 2015

My conclusions

- The scaling of LCD technology was effected through waves of application growth.
- Two of the key technologies that enabled this scaling were engineered glass substrates and PECVD/PVD platforms.
- Despite a successful technological scaling & innovation that neutralized LCD's legacy performance issues, it has been a poor economic venture for panel makers and some brands.
  - Nationalism and tardy rationalization of manufacturing capacity has led to periodic over-supply and a pathological market dynamics.
  - Good for consumer…bad for many in the LCD value chain.
- The emergence of R2R manufacture, initially for display & lighting components, may be attractive for new applications such as micro PV.