



A New Paradigm for Disruptive Technology Development and Transition

*Gregory B. Raupp, Director
Flexible Display Center at Arizona State University
ASU Research Park
Tempe, Arizona 85224
raupp@asu.edu
<http://flexdisplay.asu.edu>*

*National Defense Industry Association
7th Annual Science & Engineering Technology Conference
Orlando, Florida
April 20, 2006*



Information Displays are a Key Enabling Technology for Network Centric Operations



Source:
PEO Soldier

... and the Flexible Display Center is delivering the next generation displays



Flexible Displays Will Provide Unprecedented Performance



Next Generation Flexible Displays


- ✓ Rugged
- ✓ Lightweight
- ✓ Ultrathin / Compact
- ✓ Any shape
- ✓ Low power





Enabling the Revolution: *What was Missing in 2003?*

- Single organization with all the technology, know-how and resources required
- Driver to converge technology development on Army applications
- Strategic Plan to advance the technology to commercialization
- World Class Manufacturing Pilot Line incorporating unique toolsets required

A scenic view of the Arizona State University Research Park. In the foreground, a multi-tiered waterfall flows into a pond. The background is filled with numerous palm trees and a large American flag flying on a tall pole. A modern building is visible in the distance under a blue sky with scattered clouds.

*The U.S. Army's Flexible Display Center
at Arizona State University
Est. February 10, 2004*

Dual Mission:

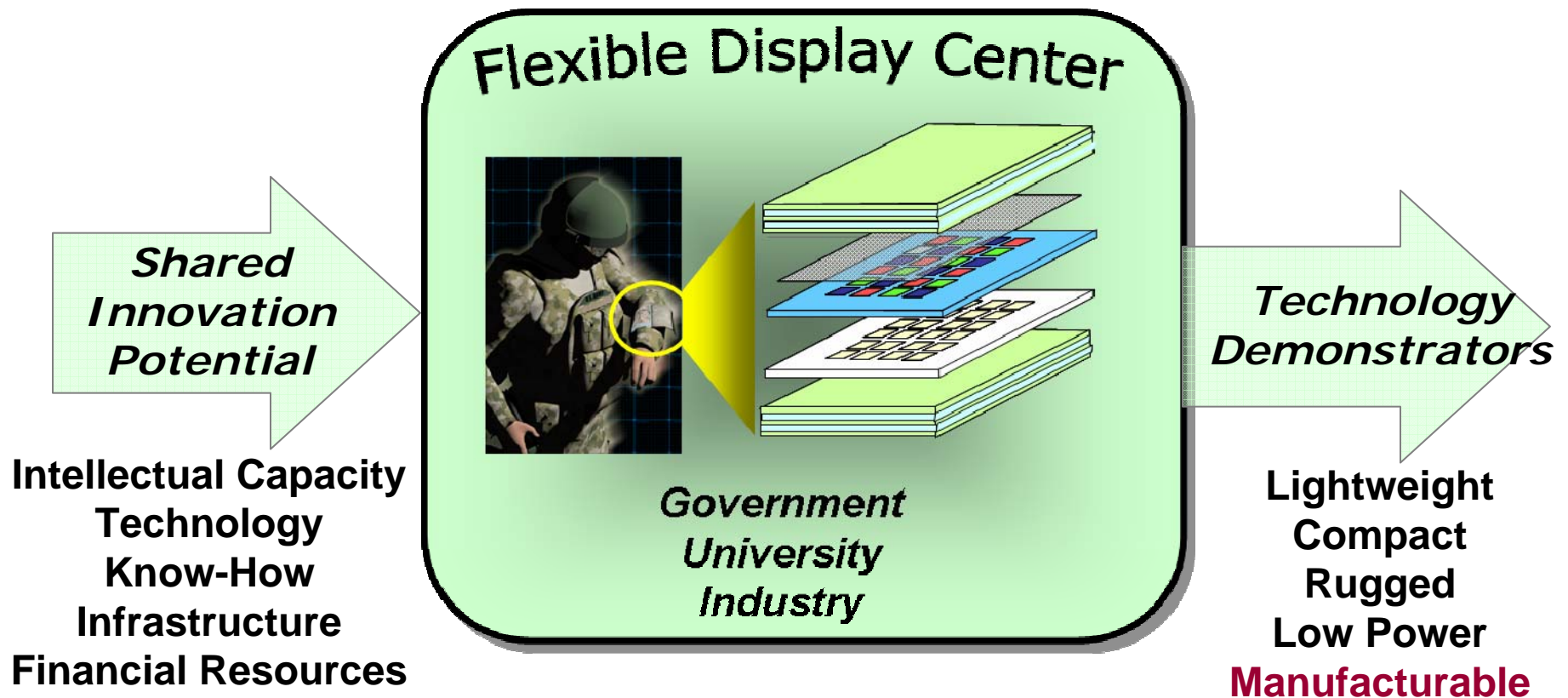
- ★ Accelerate commercialization of flexible displays
- ★ Provide flexible display technology demonstrators for Army Systems and commercial partners



Flexible Display Center

Partnership Vehicle

Rapid Innovation, Technology Development & Integration
Pilot Line Manufacturing





Innovating Military Technology Development



Devices
Low TRL
Low MRL



Demos
High TRL
High MRL



“6.2” Applied R&D
Funding

New component technologies
Technology integration

“6.7” ManTech
Funding

New process technologies
Pilot Line deployment and scale-up



Industry
Funding

Materials, processes, tools
IP, know-how, personnel



University
Funding

Facility, core toolset
Faculty, students



World Class Strategic Partnership



Frontplane
Technology

U.S. Army

Materials

Manufacturing
Toolsets
for

Flexible
Display
Center



R&D
Labs &
Universities

System
Integrators



Princeton



North
Texas



UT-Dallas



NC A&T





FDC Technology Focus

High Information Content
Low Power, Rugged, Lightweight, Flexible

Reflective
Bi-stable "zero power"

Emissive
Efficient low power

 **E·INK**
Electrophoretic Ink



KENT DISPLAYS INCORPORATED
Cholesteric Liquid Crystal



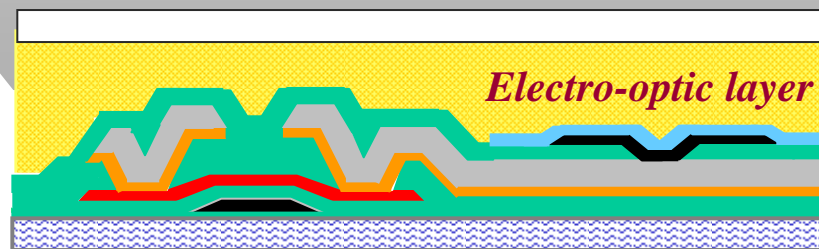
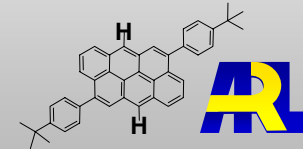
UNIVERSAL DISPLAY CORPORATION™

Phosphorescent OLED

OLED Integration



Novel Blue OLEDs



Counter-electrode

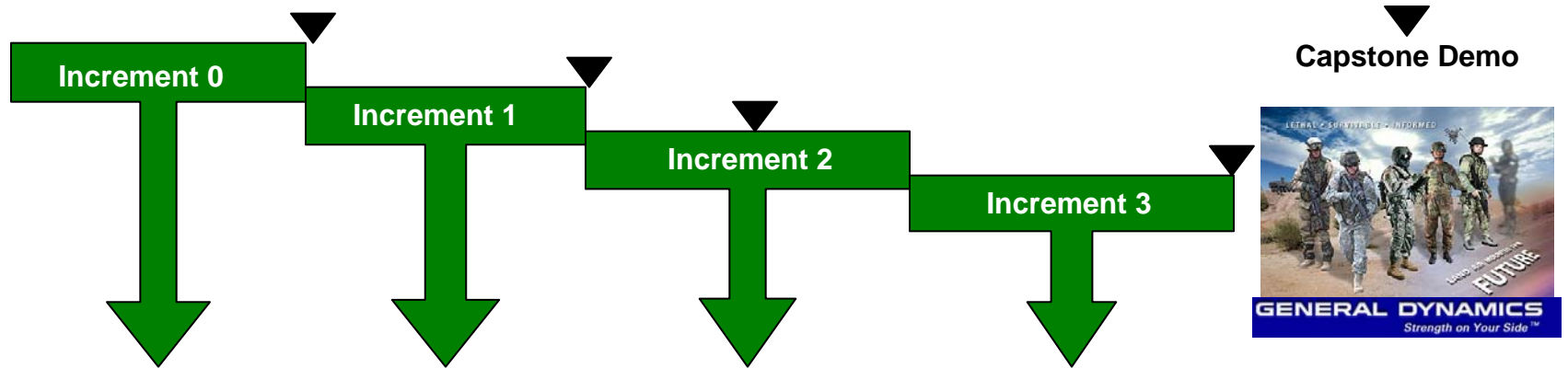
Electrode

*Thin Film Transistor (TFT) Pixel
Cross Section on Flexible Substrate*



Delivering First Technology Demonstrator to FFW in 2007

2005												2006												2007											
JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Re-Plan				System Eng Synch				Design												Build, Integrate, Test				FFW Demo											



1.1" 64x64 emissive and reflective on flex	4" QVGA reflective display on rigid	4" QVGA reflective display on flex June '06	7.5" VGA reflective display on flex May '07	Flexible reflective "plug-in ready" Sept '07 Demo
--------------------------------------------	-------------------------------------	------------------------------------------------	------------------------------------------------	------------------------------------------------------

Increment 0	Increment 1	Increment 2	Increment 3	FFW Demo
Concept Devices and Technology Demonstrators				Capstone Demo



FFW Engaged to Set Capstone Objectives and Requirements

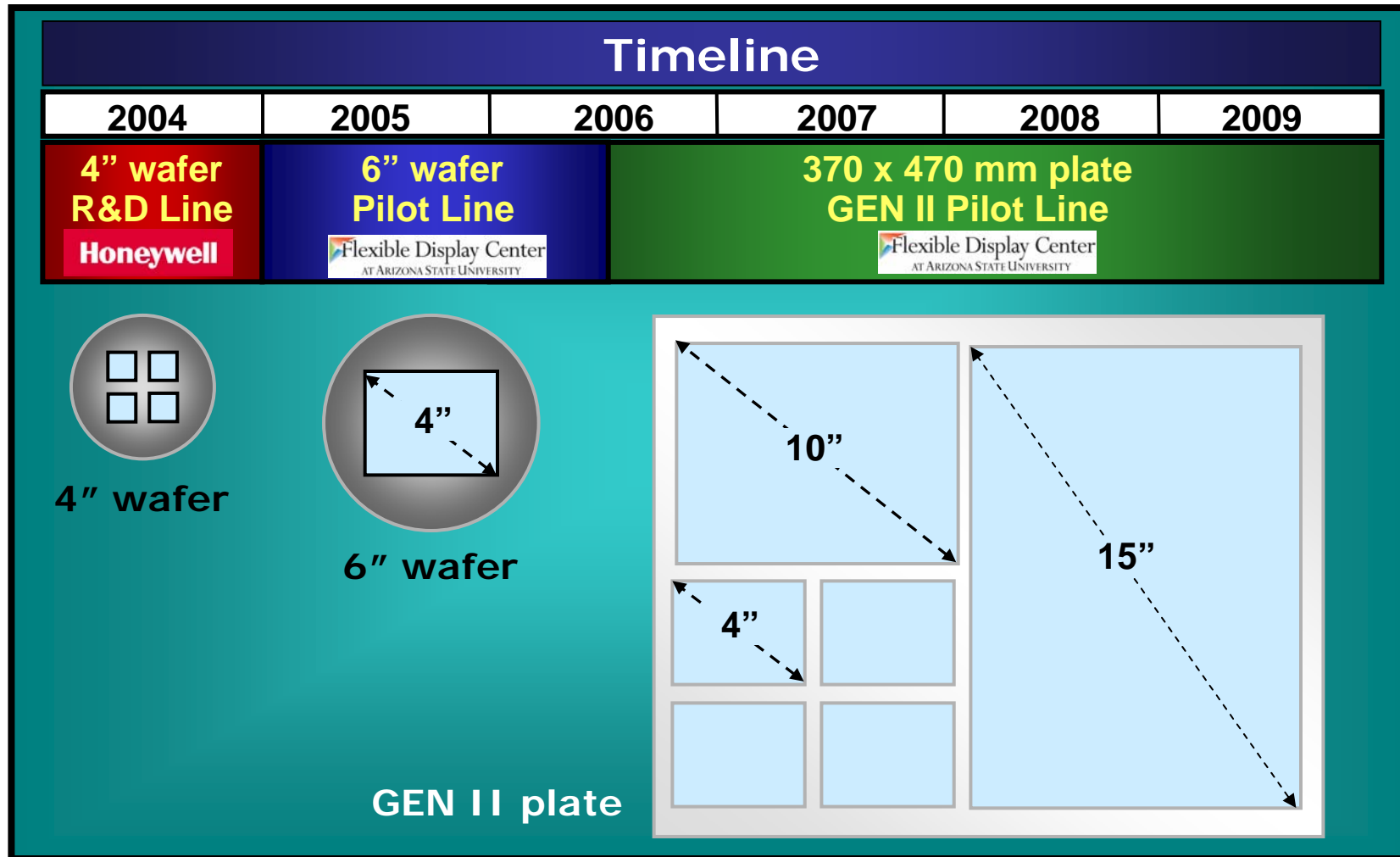


- Comprehend customer-desired display size, form factor, resolution
- Led by Andy Taylor, Chief FFW Architect

Follow-on studies and workshops culminating in formal requirements
3Q 2006



Rapid Pilot Line Deployment: Alignment with Army Programs Commercialization Acceleration





FDC Pilot Line Capability Compared to Typical R&D Line

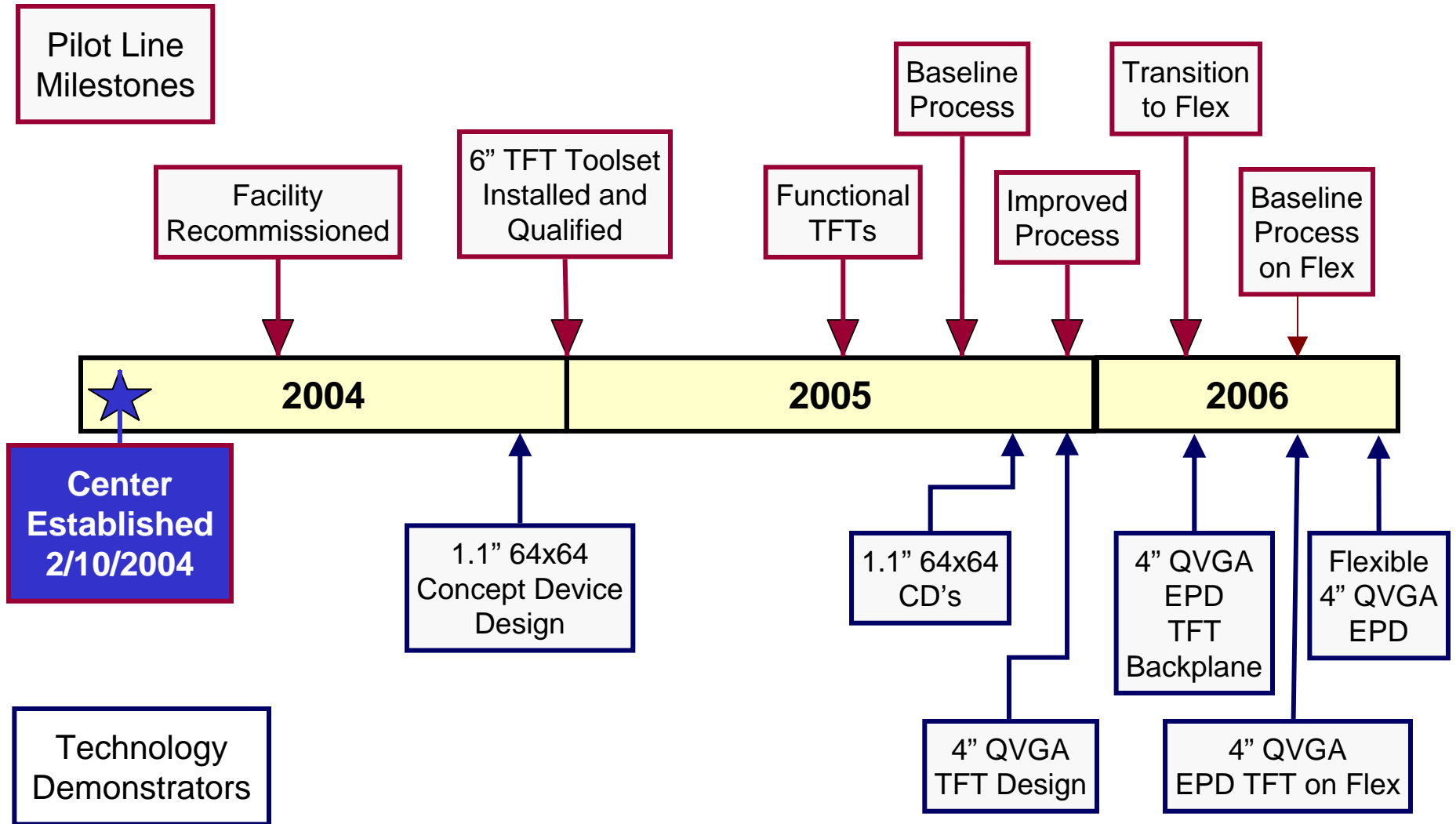


- Dramatically higher productivity:
 - ✓ Throughput
 - ✓ Cycle time
- Higher quality at high yield
- Lower unit cost

Characteristic	Academic R&D Line	FDC Pilot Line
Throughput	4-5 starts/month	250-300
Cycle time	8-12 weeks	1-2 weeks
TFT Yield	Undefined	> 90%
Staffing	Students & Post-docs	Industry Professionals
Tool Operation	Manual	Automatic
Data Collection	Manual	Automatic (MES)
Substrate Scale	Chip → 4-6" Wafer	6" Wafer → GEN II
Display Unit Cost	High	Moderate

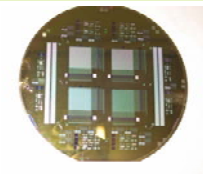
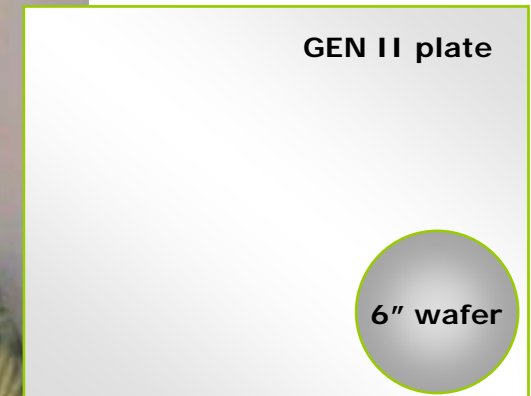
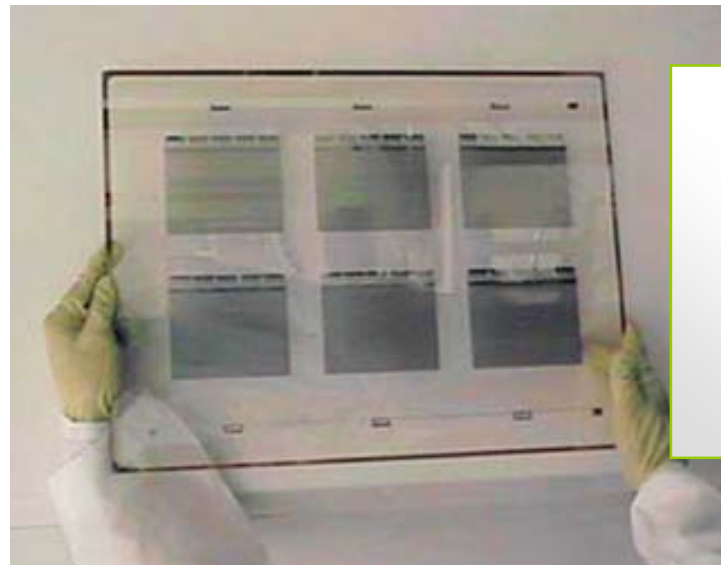


Technology Demonstrators linked to Pilot Line and Backplane Milestones



Manufacturing Scale-up to GEN II

- Only Pilot Line of this scale and sophistication dedicated to flexible display development
- Demonstrates manufacturability and scalability
- Provides vehicle for producing large form factor (17") custom displays for the Army and partners
- Requires custom designs and modifications of conventional process tools

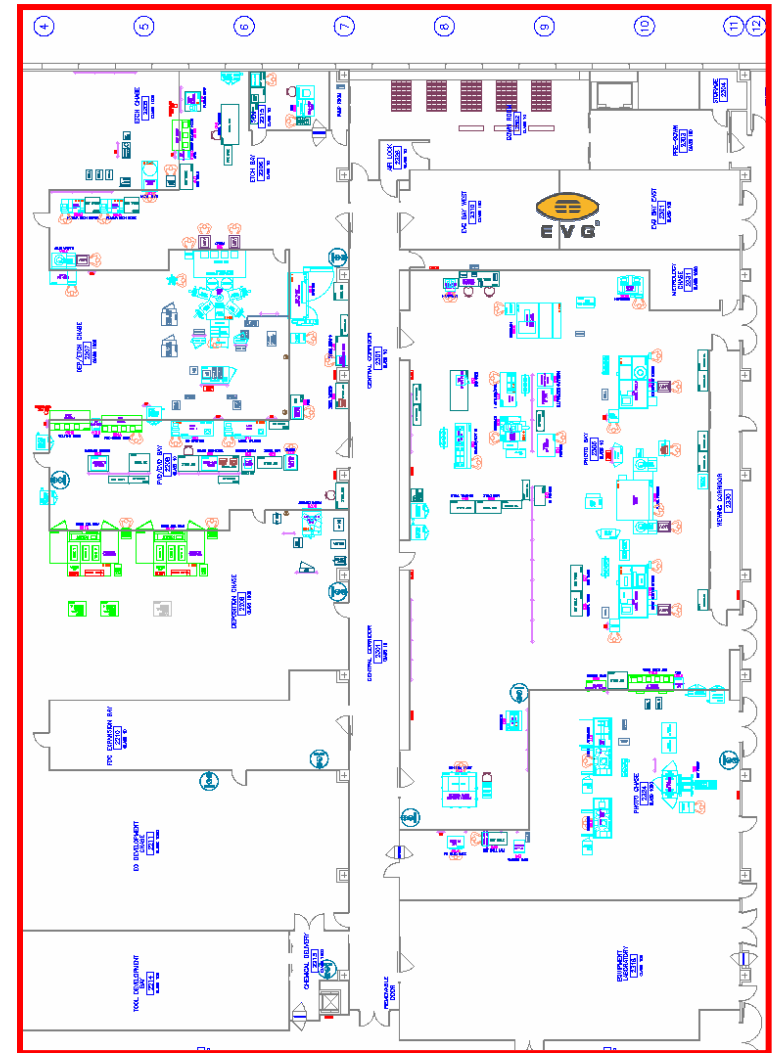
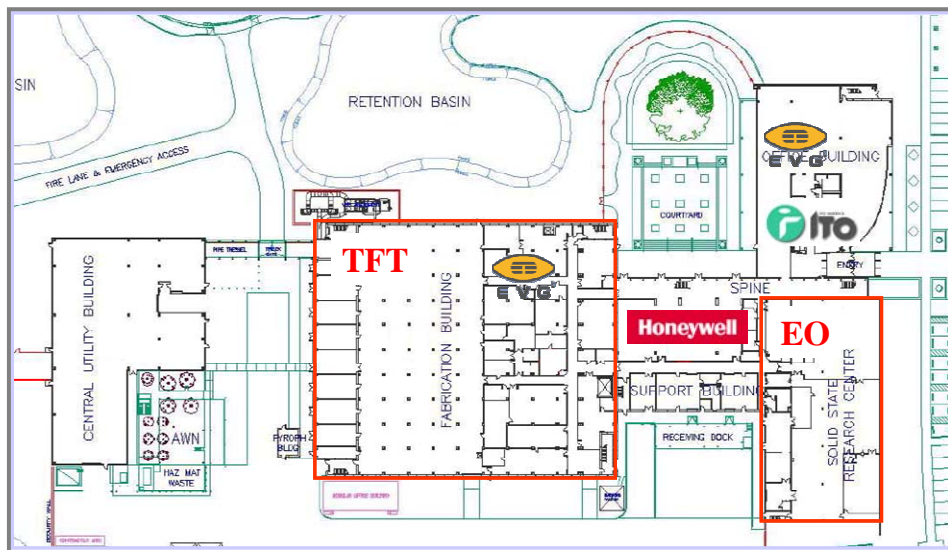




World Class Display R&D to Manufacturing Facility

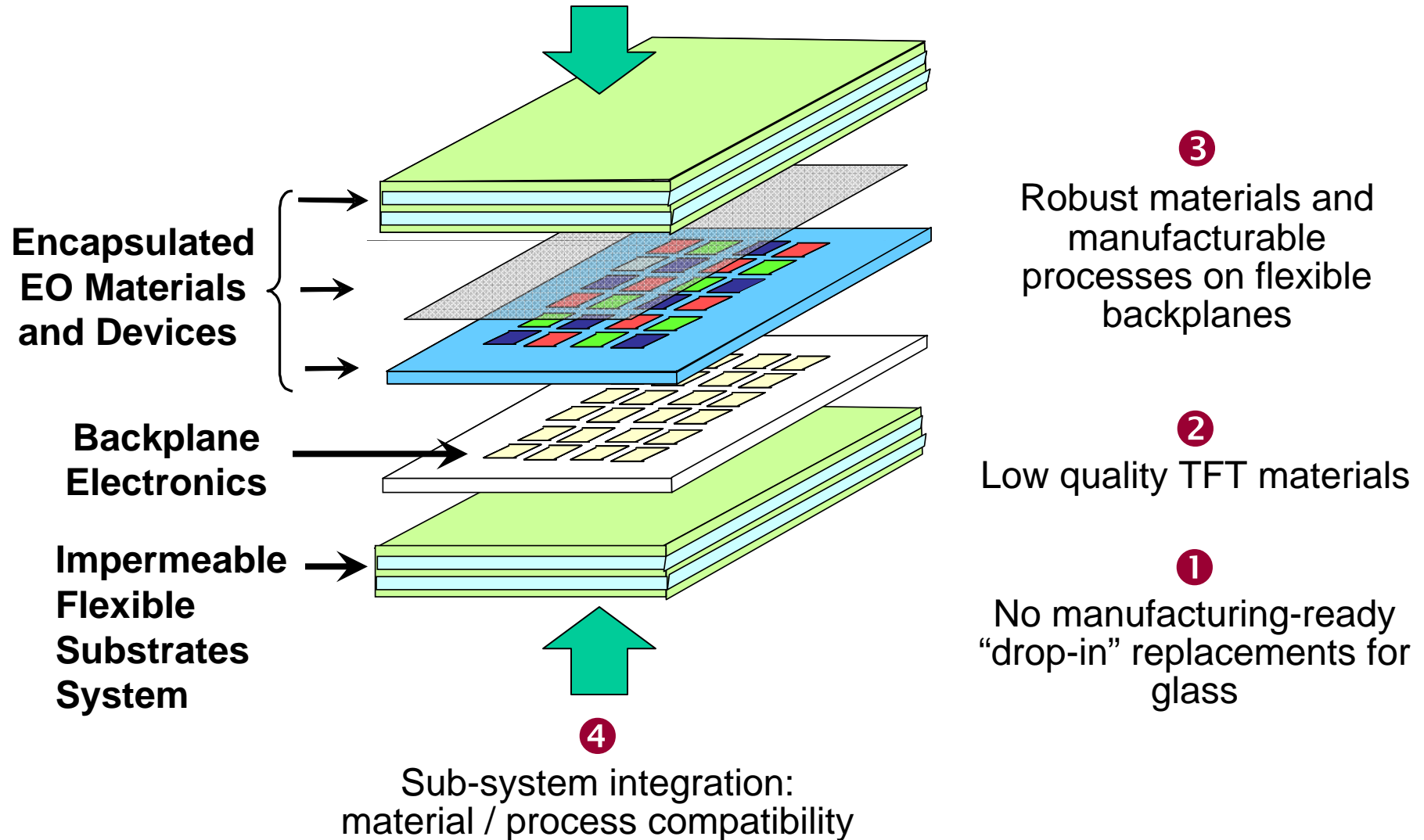


- State-of-the-Art Infrastructure
- 250,000 SF total capacity
 - 43,500 SF Cleanroom
 - Pilot Line and Production capable
 - 22,000 SF Wet / Dry Labs
- Flexible subdivision for partner co-location



TFT Fab

FDC is Attacking Key Technology Challenges



FDC Technology Solutions

Substrate Bond/De-Bond



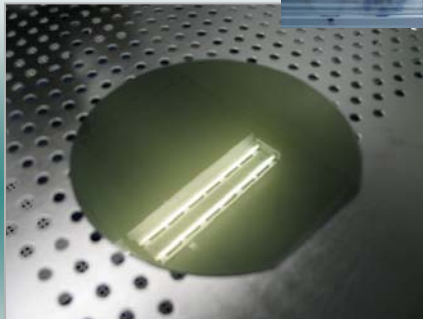
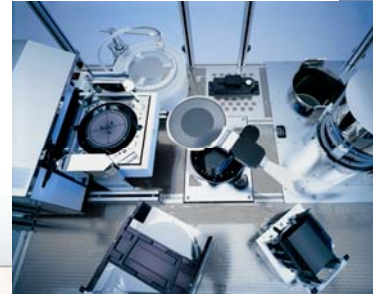
- Pilot Line Tools
- Novel Adhesive Materials
- Manufacturable Processes



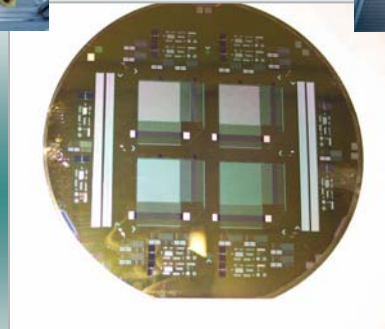
EVG 850



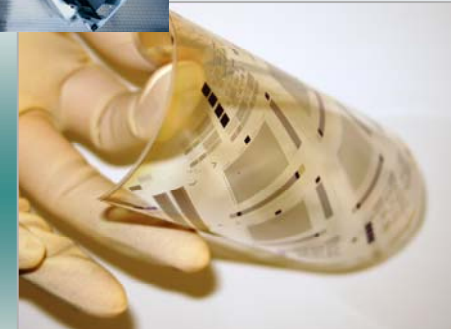
EVG 850



Bonded substrate



After TFT Fab

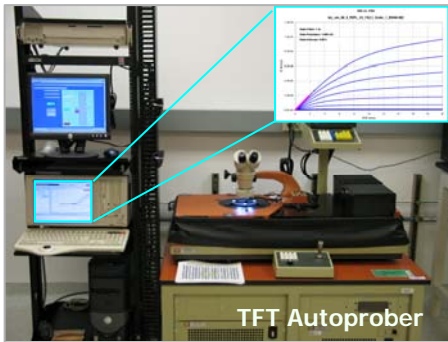


Debonded substrate



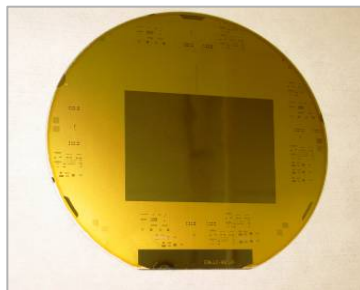
FDC Technology Solutions

Rapid Cycles of Learning: TFT design, fabrication, testing



TFT Autoprober

FDC custom auto-probe
24,150 TFTs CY 2005
5,840 TFTs 1Q 2006

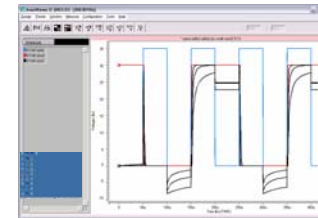
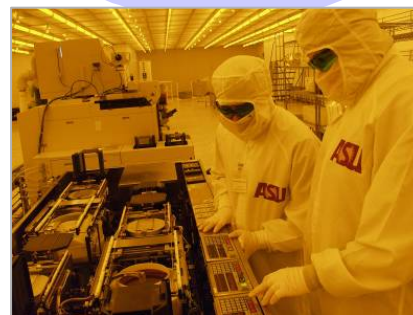


Fabricated array

TFT Testing & Parameter Extraction

TFT Array Simulation, Design, Layout, Verification

Pilot Line Fabrication

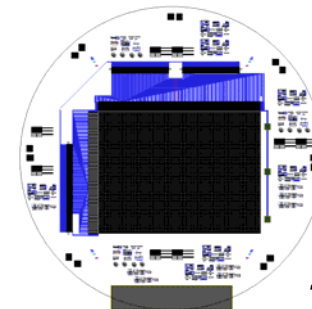
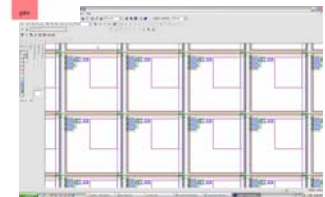


Proposed Design Rules

• MET1 - source/drain metalization

Rule	Description	Lambda	Micron
7.1	Minimum width	3	4.5um
7.2	Minimum spacing	3	4.5um
7.3	Minimum overlap of any contact	2	3um

Design Rules for high manufacturing yield



4" QVGA Maskset



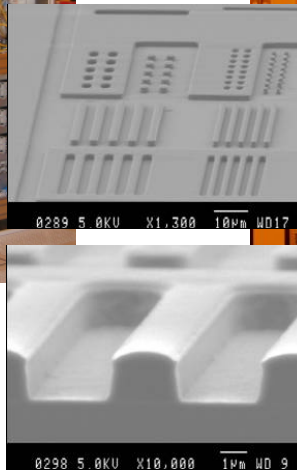
FDC Technology Solutions

*Unique GEN II Toolset
for patterning large area flexible substrates*

EVG FDC Photoresist Coater



Azores 5200 gT Stepper



Alpha Tool

high uniformity with
unprecedented material
utilization efficiency (> 90%)



World's First
photolithography tool
with flexible substrate
distortion compensation

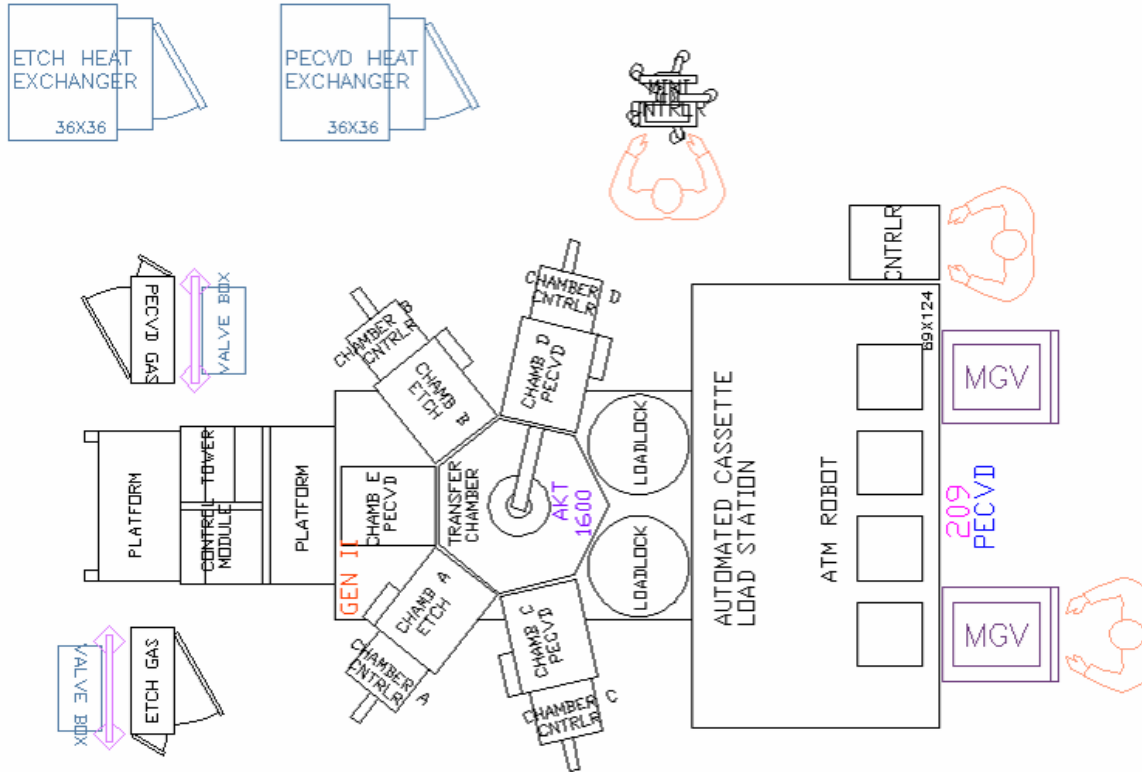


U.S. Display Consortium



FDC Technology Solutions:

Unique GEN II Tool for large area flexible substrate thin film dep/etch

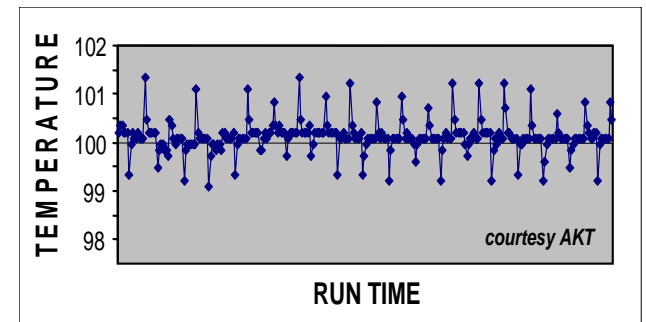


AKT 1600
3 PECVD Chamber
2 Etch Chamber

Hybrid design by AKT to FDC specs

2nd AKT Pilot Scale tool dedicated to flex

New “active cooling” deposition chamber design for accurate T control





Summary

- The FDC was established to accelerate commercialization of flexible displays and to provide new, early capability to the Army
- The FDC has created a one-of-a-kind partnership to enable rapid development of dual-use flexible display technology and transition to the military and commercial world
- Rapid deployment of Pilot Lines
 - ✓ 6” wafer-scale Pilot Line for rapid technology development
 - ✓ Producing 4” QVGA backplanes and TDs
 - ✓ Tools, materials and processes developed to enable processing on flex
 - ✓ Unique GEN II Pilot Line to demonstrate manufacturability and scaleability
- The Strategic Plan is being executed on or ahead of schedule



New Capability for the Soldier-- New Opportunities for Industry





Acknowledgements

- ASU and The Flexible Display Center gratefully acknowledge the substantial financial support of the U.S. Army through Cooperative Agreement W911NF-04-2-0005
 - ✓ Dr. David A. Morton, ARL, Cooperative Agreement Manager
 - ✓ Mr. Henry Girolamo, U.S. Army NSC, Associate PM Integration
 - ✓ Dr. Eric Forsythe, ARL, Associate PM Technology
- FDC Principal Members: *EV Group, Honeywell, UDC, USDC*
- FDC Associate Members: *E Ink, Kent Displays, Corning, Ito America, Abbie Gregg, Inc., Surface Science Integration, Rockwell Collins, Nitto Denko, Litrex, DuPont Teijin Films*
- FDC Technology User Members: *General Dynamics, Raytheon, L-3 Communications*