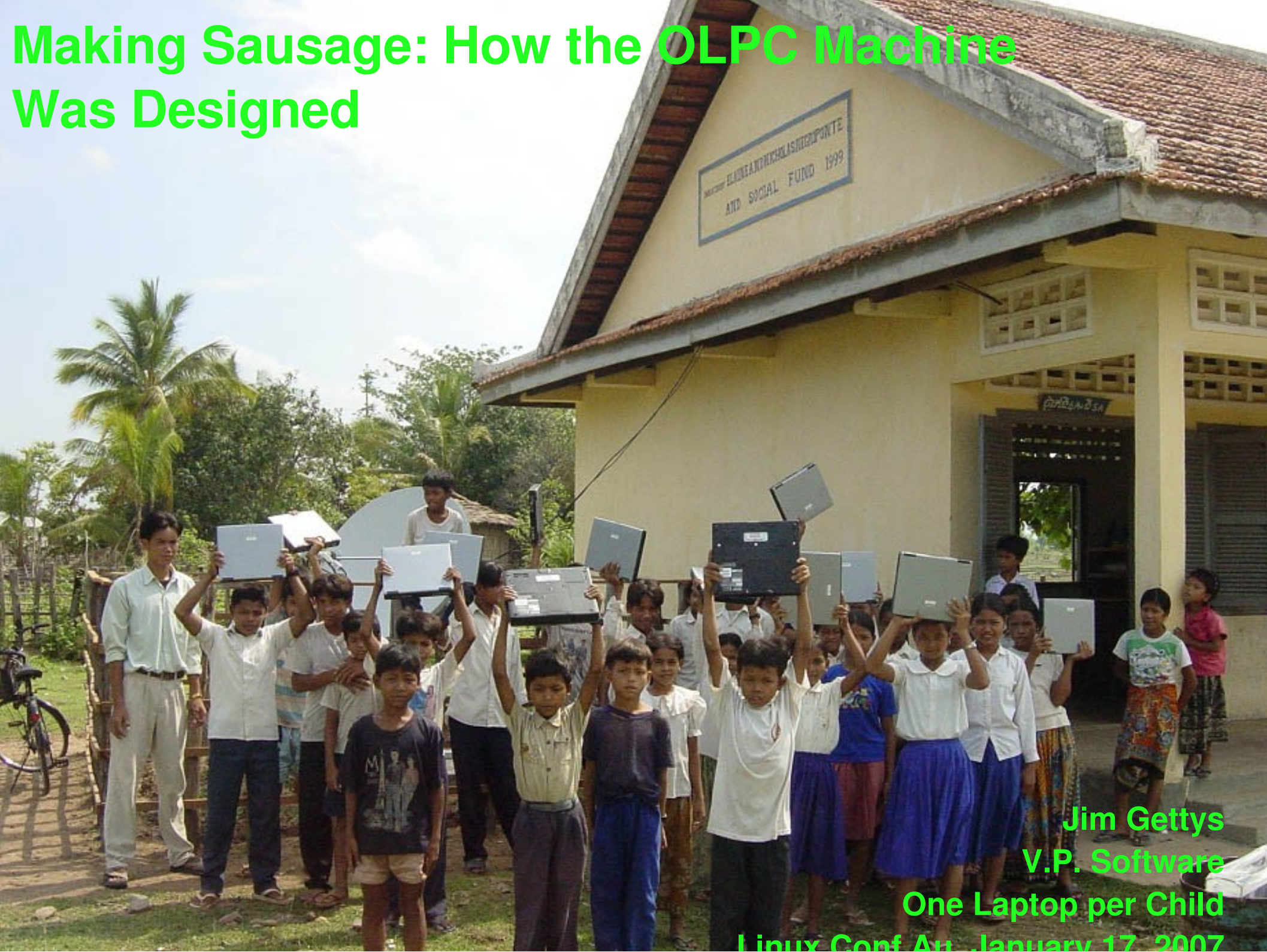


Making Sausage: How the OLPC Machine Was Designed



Jim Gettys

V.P. Software

One Laptop per Child

Linux Conf Au, January 17, 2007

Agenda

- **Our mission**
- **How would one design a laptop for Children?**
 - **Core Architecture**
 - **Mechanical Design**
 - **Power System Design**
 - **ASIC Architecture**
 - **Power Management**
- **Software**
- **Summary / Q&A**

Sausage Making

- You can only make as much sausage as you can get ***all*** the ingredients for
- Some parts of the recipe can be substituted, but not others
- There are a finite number of ingredients
- if you make a ***lot*** of sausage you may be able to get custom ingredients made
- Major ingredients take years to grow, rather than a season.
- You can let the farmer know what kinds of ingredients you'd like the next time, and have to live with those ingredients that are available in the quantity you need
- It isn't a pretty process.
- You must cook before tasting



The mission

to develop a low-cost laptop — a technology that could revolutionize how we educate the world's children

Who?

**The 1.5 billion children
in the developing world**



Our World



ONE LAPTOP PER CHILD





Children at a FCT school in Jahi

ONE LAPTOP PER CHILD





Hassounah

Sometimes the riskiest path
is the status quo.





ONE LAPTOP PER CHILD

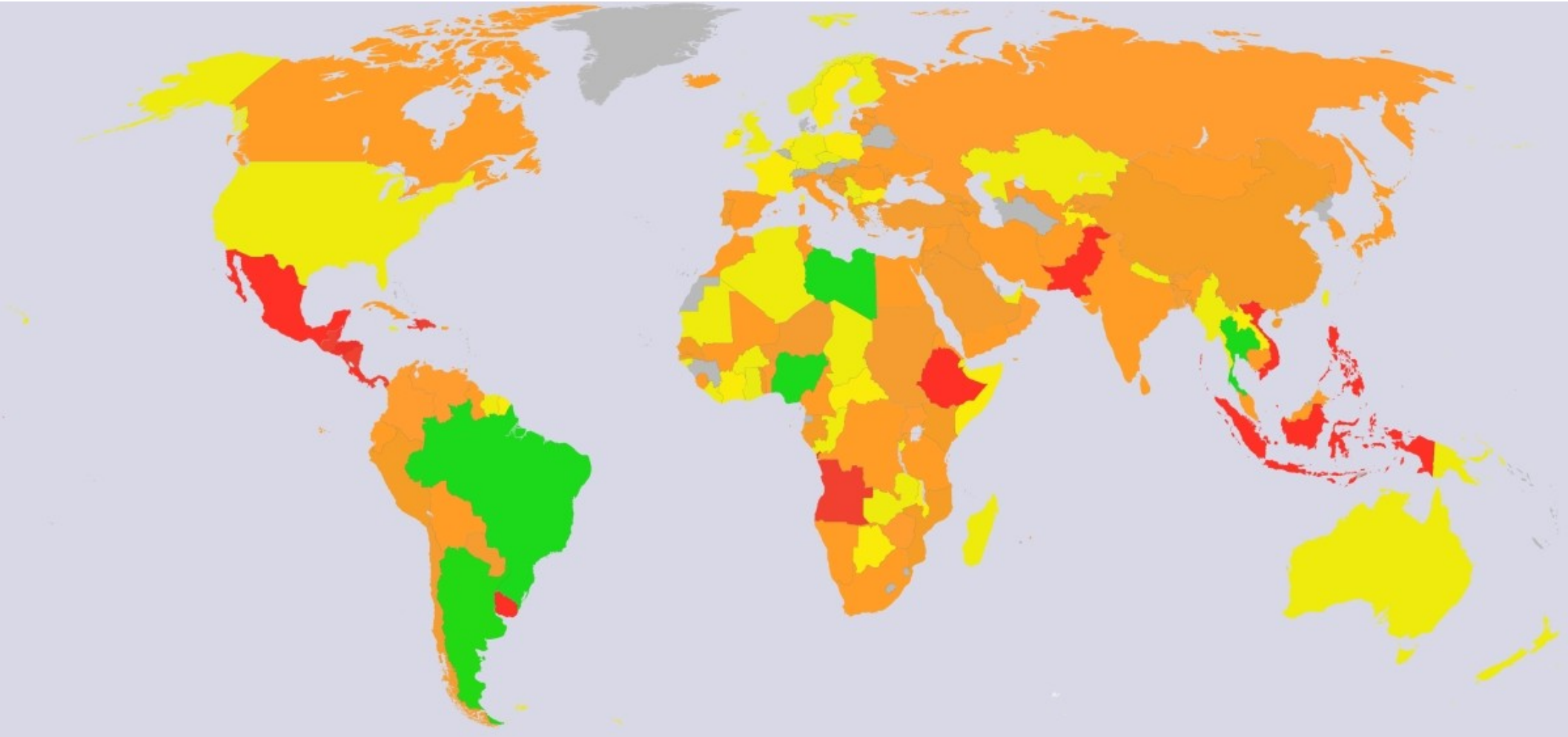




ONE LAPTOP PER CHILD



Where?



ONE LAPTOP PER CHILD



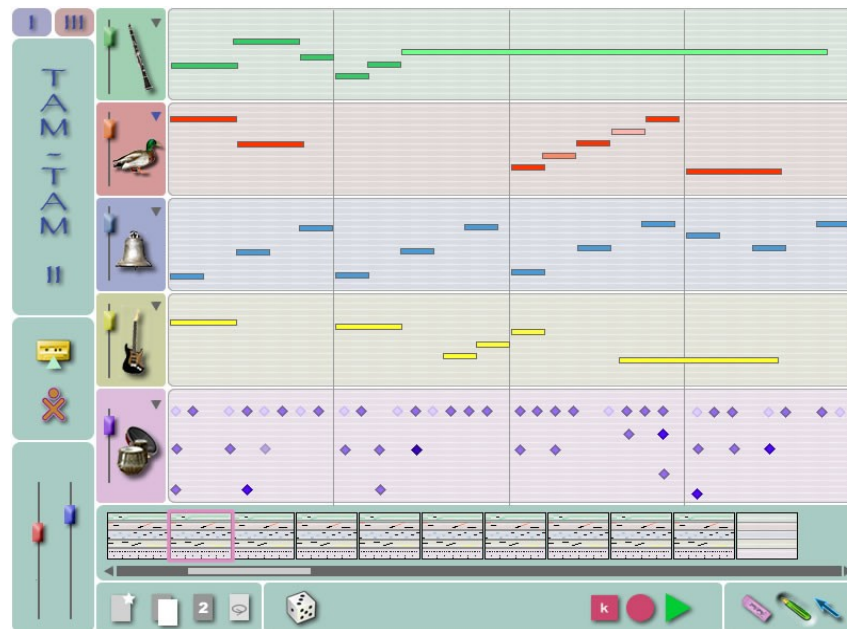
Our premise: Children lack opportunity, not capability

High-quality education *for all* is essential to provide a fair, equitable, economically and viable society; access to laptops—*on a sufficient scale*—provides real benefits for learning.

Children will be both consumers *and* creators.



&



ONE LAPTOP PER CHILD

Learning learning by debugging.



A. Burton

They'll share their learning through networking.

Learning is maximized when ideas are shared and is made part of the everyday social experience. Children (and teachers) should be able to build upon each other's ideas, experience and knowledge.

ONE LAPTOP PER CHILD





Connectivity

- Child to child communication is as important as child to Internet and child to teachers
- Wireless / Unlicensed / Build it Yourself
- Bandwidth is a perishable commodity

ONE LAPTOP PER CHILD





ONE LAPTOP PER CHILD

olpc



ONE LAPTOP PER CHILD

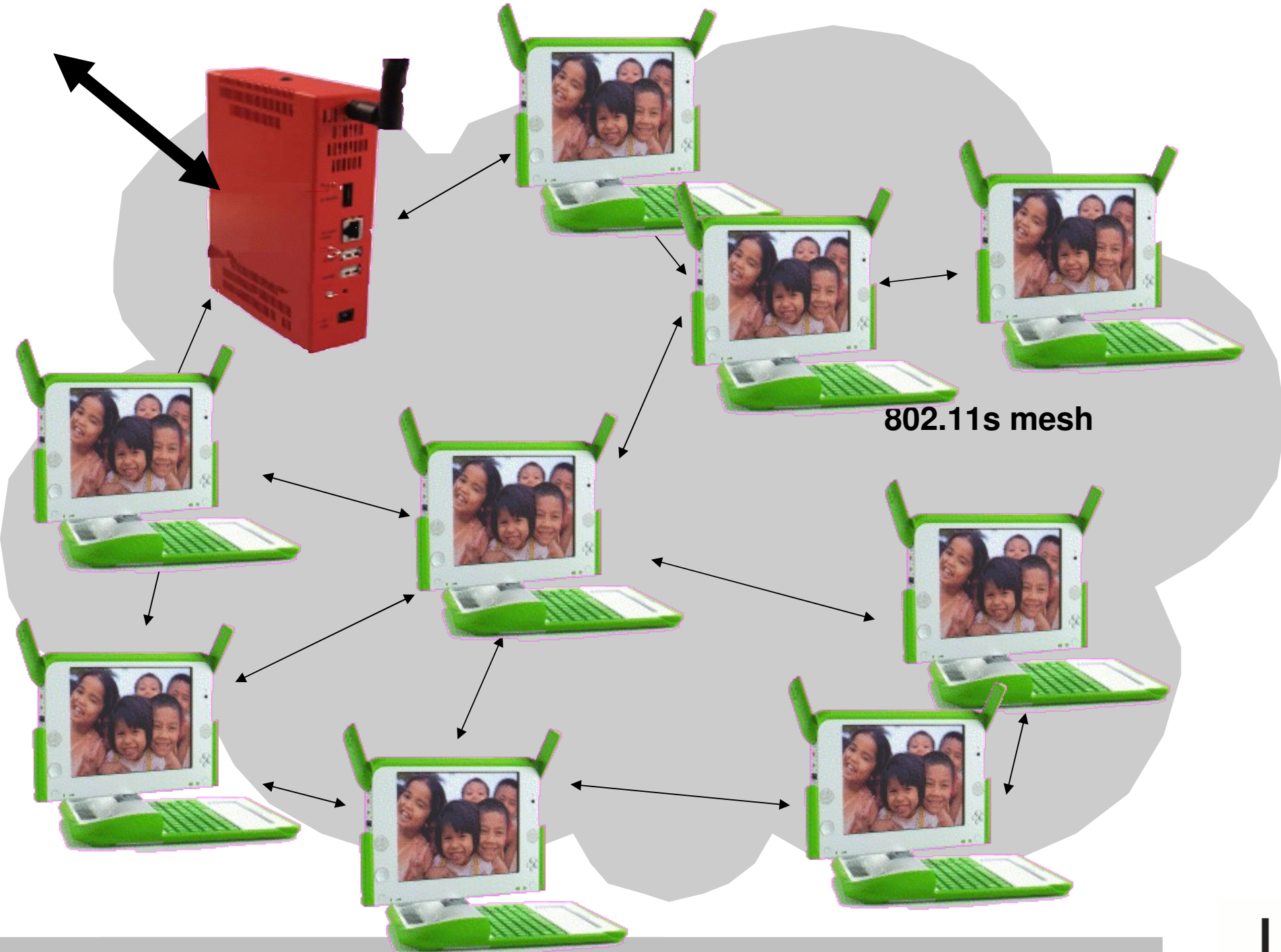




Build it yourself!

ONE LAPTOP PER CHILD

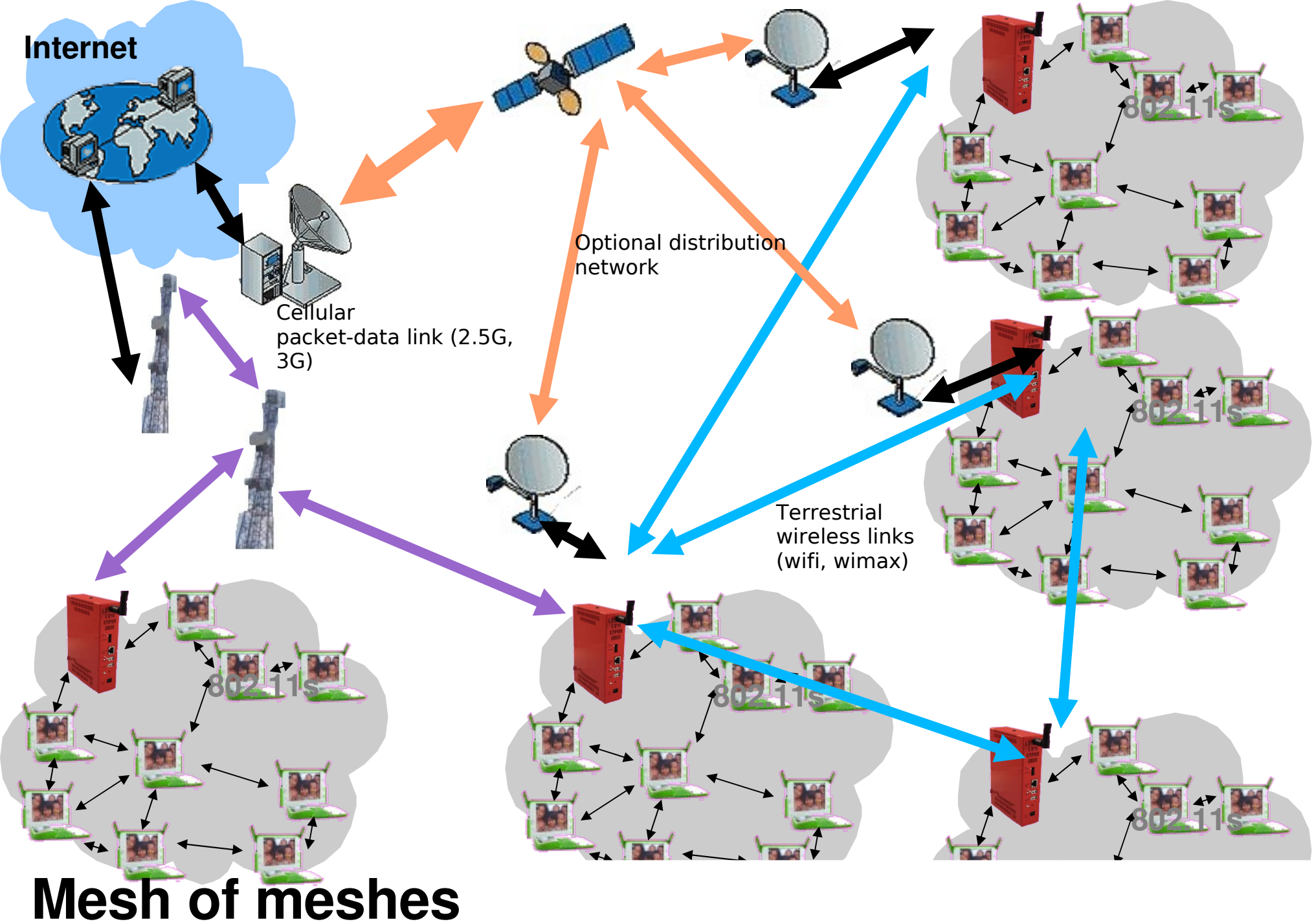




802.11s mesh

ONE LAPTOP PER CHILD







How would one design a laptop for children?

ONE LAPTOP PER CHILD



A child's laptop is:

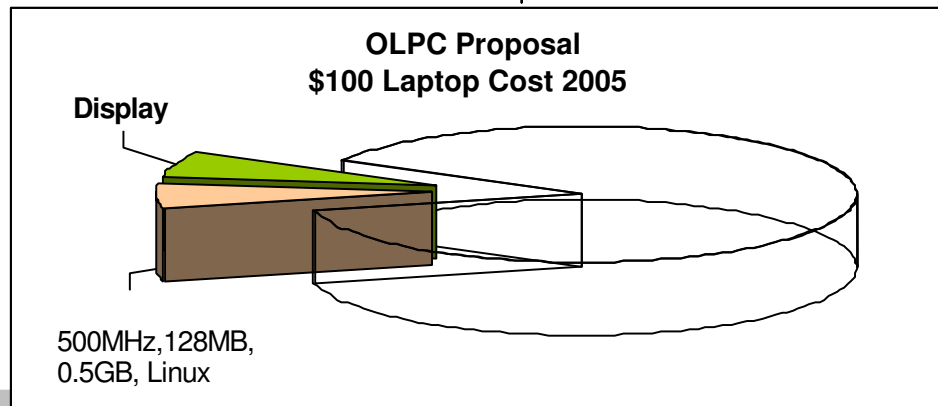
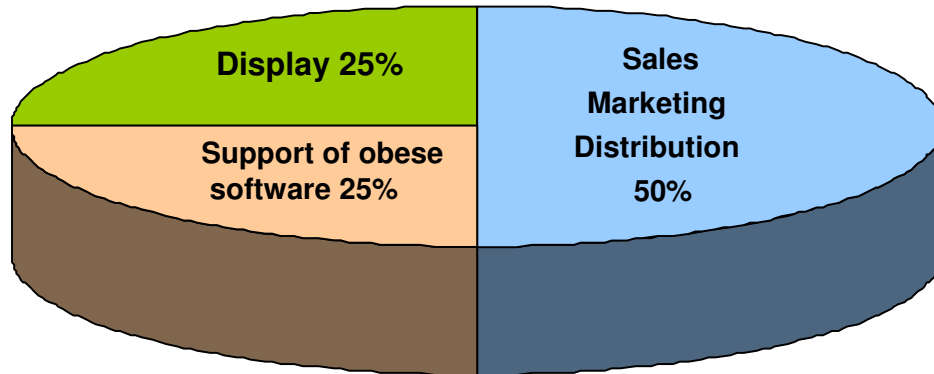
- Safe and robust;
- Light to carry;
- Vibrant to look at;
- Low power; Used outdoors;
- Helps them communicate and interact;
- Encourages them to express themselves;
- Lets them engage in open-ended discovery;
- And of course... inexpensive!

Challenges

- **Infrastructure**
 - *Power*
 - *Connectivity*
- **Political uncertainty**
- **Physical environment**
- **Effective distribution**
- **Inefficient software**
- **Cost**

Getting to the \$100 Laptop

Gross Breakdown in Laptop Costs 2005



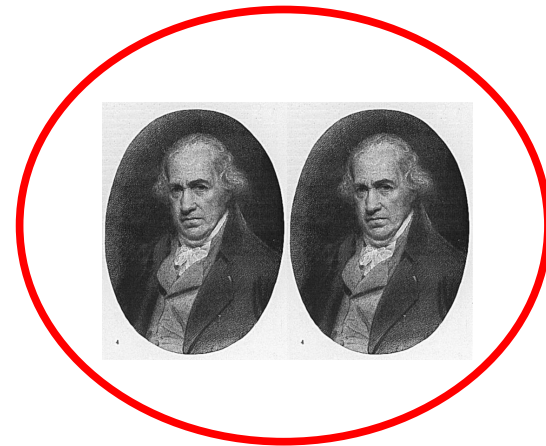
HOW:

- No Sales, Marketing, Distribution
- First Purchase Order 5-10M units
- Linux
- Reduce display cost leveraging back light innovation

ONE LAPTOP PER CHILD



How many Watts?



ONE LAPTOP PER CHILD

2.5-3.5 Watts Not Good Enough

- A small child can generate 5-10 watts
 - Less than we had hoped, for less time
 - How to get to to a reasonable return for the effort ratio? 10X has been our goal
- Mesh network demands wireless be **ON**
 - To forward packets for others
 - *If the child is not confident there will be power when they need it, they will try to disable the wireless*
- *The CPU is usually just:*
 - *refreshing the screen*
 - *forwarding packets*

Necessity is Mother of Invention

- Turn off the CPU and most of the system: only leave wireless and possibly display
- DCON chip allows autonomous display
 - UMA devices are bad for low power use
 - We can take over display from CPU using DCON chip and small RAM chip, saving most of the power, and costing \$1 - \$2.
- Marvell wireless can operate autonomously
 - Outboard ARM core, with 192 Kbytes RAM
- Results: .5 to 1.5 watts, depending on screen and wireless use, we believe
 - 22 watt hour battery should have good life

The Good, the Bad, and the Ugly

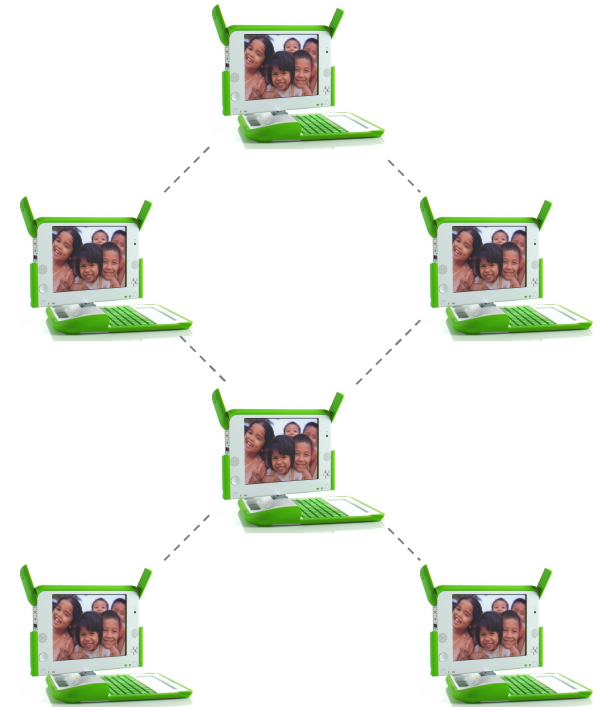
- Turning off the CPU gets us to our power consumption goal
 - DCON and Marvell Wireless makes this work
- The Geode GX2 takes ~25 milliseconds from power on to running, and we need a frame time to take over control of the display (up to 50ms)
- CHI studies indicate that this is perceptible
 - Can't turn off the CPU between each keystroke
 - And S1 is broken!
 - But we can turn off the cpu every pause in use

Additional Novel Power Tricks

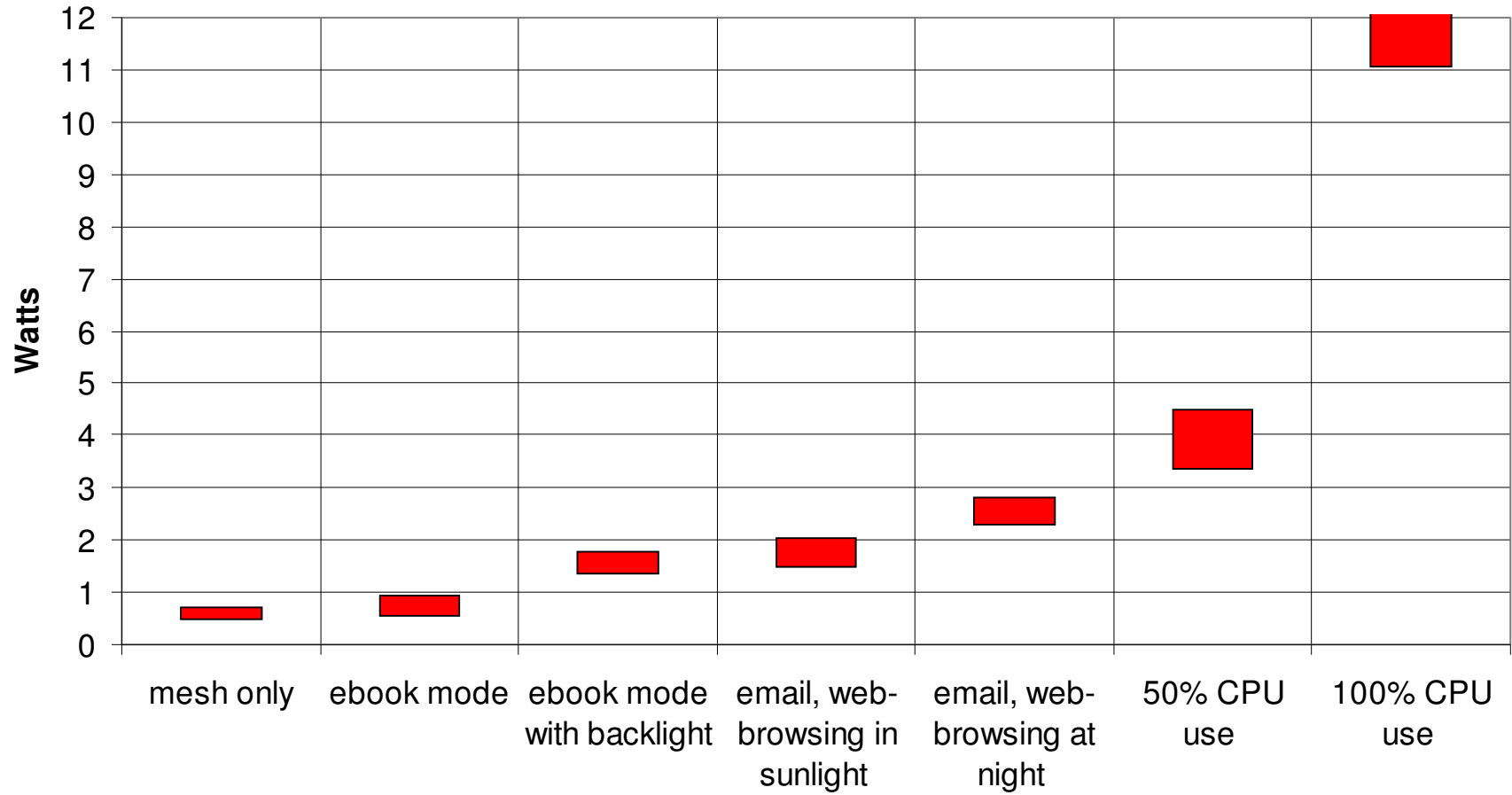
- Drive the flat panel slowly whenever possible, to save power
 - Not novel to us – Cellphone chips and panels are doing likewise
 - Simple to add to the X Window System and fbdev device driver using either UMA graphics or DCON chip
 - Dynamic screen update rate change as applications need it

Wireless Mesh

- 802.11G-based ▶ IEEE 802.11S
- Extended antennas: +3 dB gain
- On-chip ARM9 CPU + 192K RAM
- Autonomous mesh router
- Complete infrastructure
 - *School Server w/DVB-S Receiver*
 - *Solar-powered Access Points*
 - *Segmentation: spatial & frequency domain*
- 24 hour/day wireless router



\$100 Laptop Power Consumption Estimates Ranges



ONE LAPTOP PER CHILD



Power Management



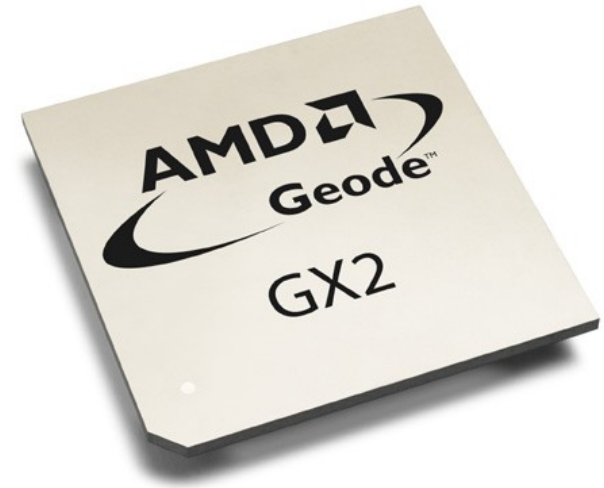
- **TANSTAAFL... NOT!**
- **OLPC's Top Priority**
- **Suspend and resume to/from RAM**
 - *CPU shuts down, RAM contents preserved*
 - *Conventional notebooks: ~10 seconds*
 - *OLPC: < 100 mS*
- **DCON: Screen stays active**
 - *System appears to be running*
- **User activity: instant wakeup**
- **Target power consumption: 2.0 Watts avg.**

Cost Reduction

- **Architected for low cost**
 - *Custom ICs*
 - *Consumer Electronics interfaces*
- **Large volume is key**
 - *Common configuration crucial*
- **Direct distribution**
- **Open source software**
- **Optimized software**
- **Power management!**

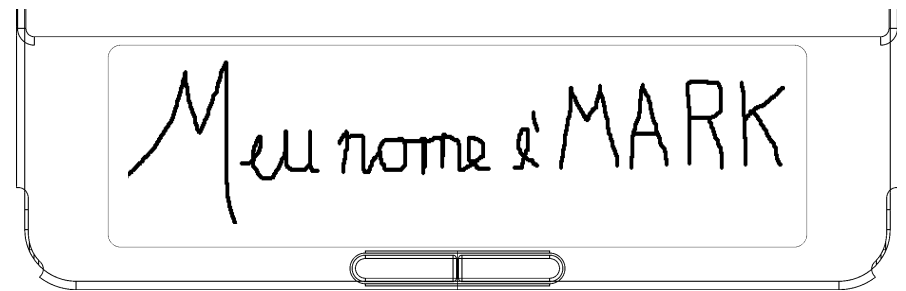
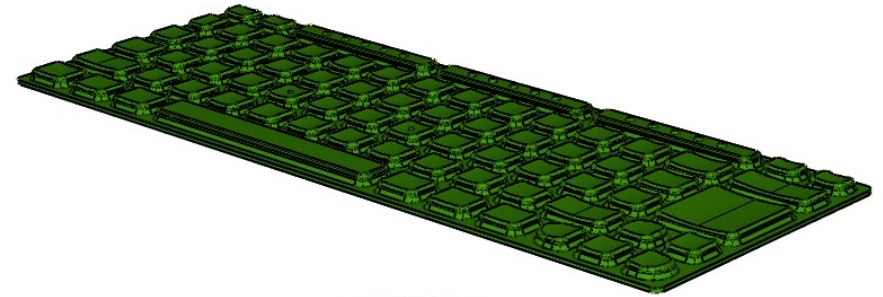
Core Architecture

- **AMD Geode GX2-500 CPU**
- **On-chip LCD interface**
- **128MB DDR SD-RAM**
- **1MB SPI Serial Flash**
- **USB 2.0 ports (3)**
- **SD Card slot**
- **Integrated wireless**
- **Audio and video support**
- **512MB LPC NAND Flash Storage**
 - *Compressed JFFS2 filesystem: ~1 GB*



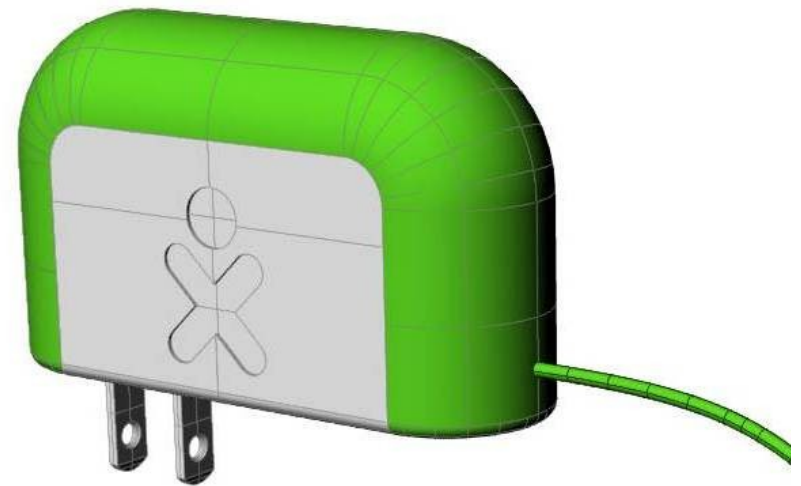
Input Devices

- **Game Pad/Controller**
- **Sealed Keyboard**
 - *Keyboard light*
- **Dual-Mode Touchpad**
 - *Capacitive input via fingers*
 - *Resistive input via stylus/stick*
- **Internal microphone**
 - *Sensor mode for learning*
- **VGA Camera**
 - *Still, Video, Sensor modes*



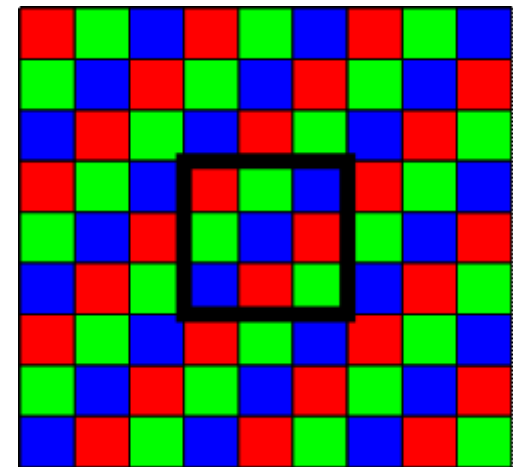
Power System Design

- **Power is unreliable, poor quality**
 - *Wide-ranging DC input: 10-24V*
 - *Overrange/polarity/surge protection*
- **Safety First!**
 - *NiMH Battery*
- **2,000 battery cycles**
- **Gang charger**
- **Human power input**

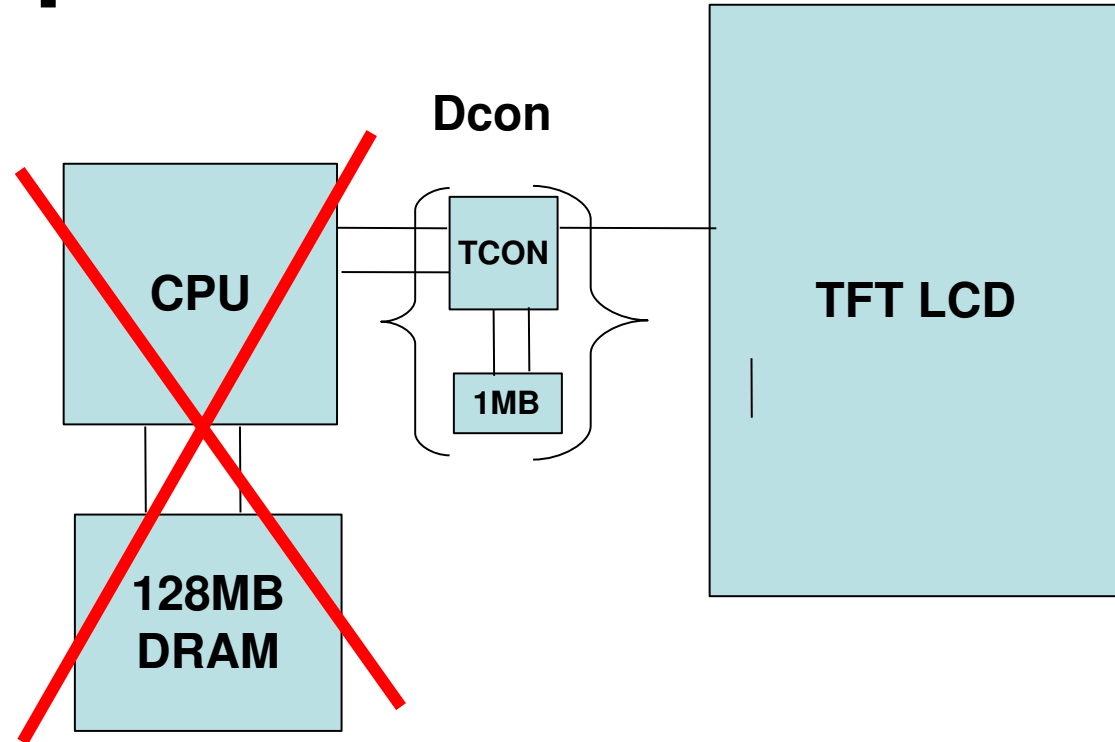


LCD Display

- Custom 7.5” TFT LCD
- 1200x900 Resolution: 200 DPI
- Dual-mode capability
 - *Reflective Monochrome*
 - *Transmissive Color*
- Unique pixel structure
- Cost effective
- Ultra low power consumption

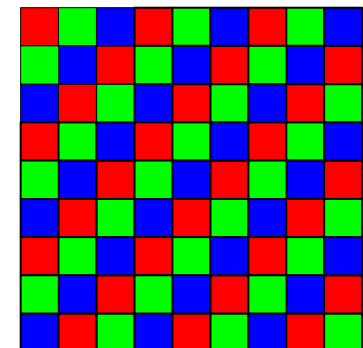
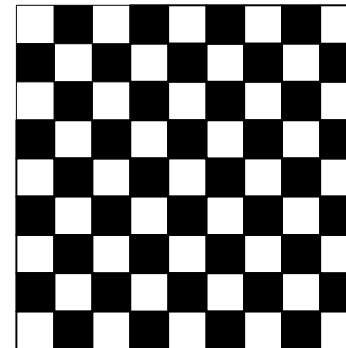


Low Power Operation = DCON

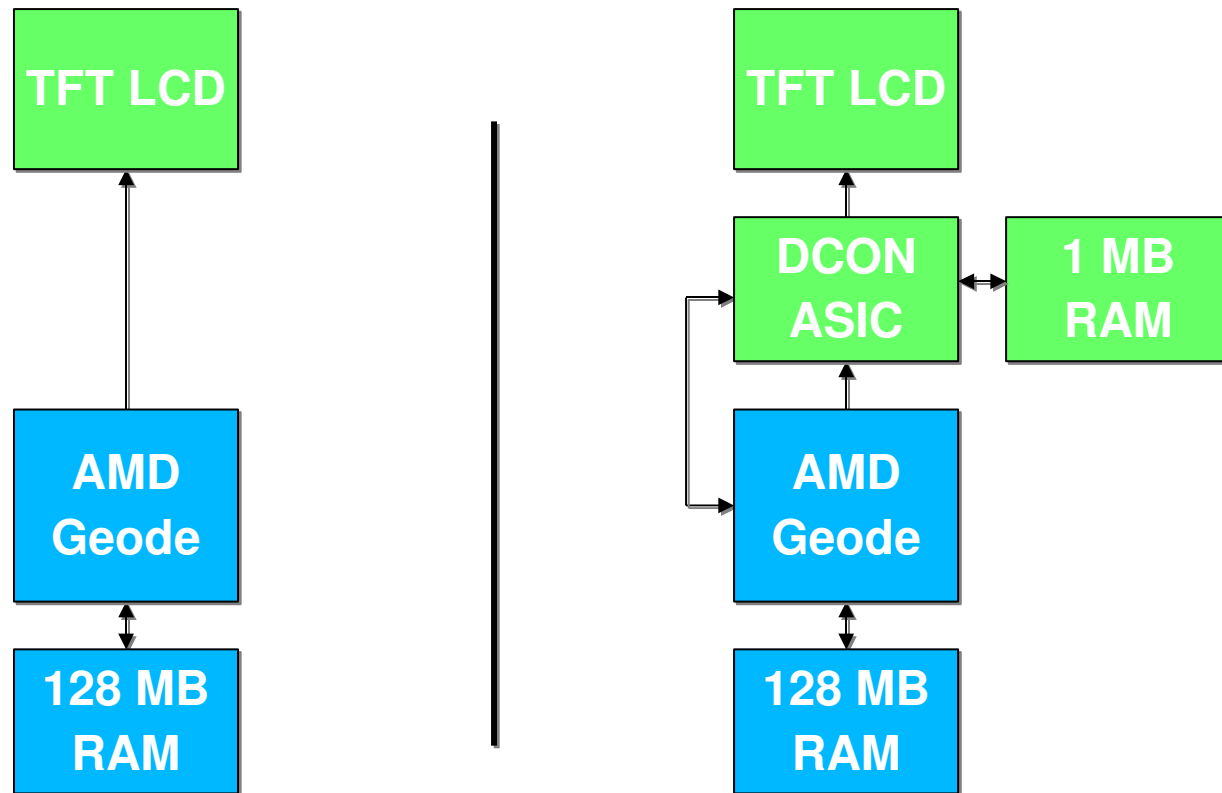


DCON = TCON

- + Self refresh
- + Panel compatibility
- + Color-> mono mode
- + Color Anti-aliasing
- + TTL-> PPTTL conversion
- + Display Power Control
- + Re-synchronization (auto-sync)
- + No PCB on panel



DCON Architecture



ONE LAPTOP PER CHILD

CAFÉ ASIC

- **Challenge:**
 - *Seek faster storage interface*
 - *Countries desire storage expansion*
 - *Camera for new user interface*
- **CAFÉ – Camera And Flash Énabler**
 - *Bus-mastering PCI interface*
 - *NAND Flash controller: Storage interface*
 - *Secure Digital (SD) Slot: Expansion*
 - *Camera Interface*

Dual Mode Display

BENEFITS

Sunlight Readability

- ✓ Standard laptop LCDs aren't sunlight readable

Cost

- ✓ 1/3 the cost of typical laptop LCD

Power

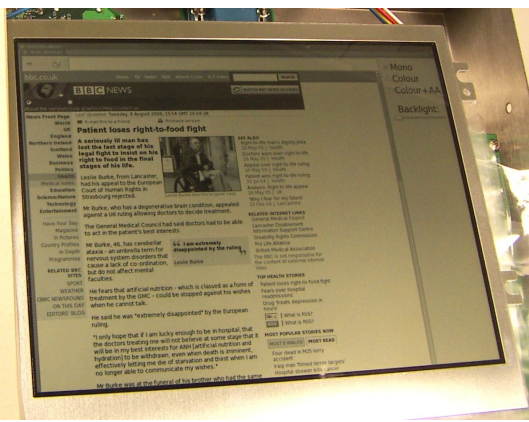
- ✓ Between 2-14% of typical laptop display power consumption
- ✓ 1 Watt power usage with backlight on
- ✓ 0.1-0.2Watts power usage with backlight off
- ✓ **Self-refresh mode (CPU can be OFF!)**

Resolution

- ✓ Higher resolution than 95%

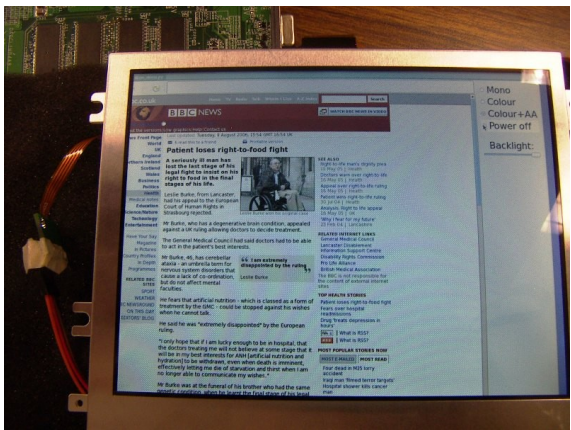
Mode 1:

SUNLIGHT READABLE
1200x900 (200 dpi)
Greyscale



Mode 2:

BRIGHT at NIGHT
Up to 1024 x 768
Color



High volume mass production in early 2007:

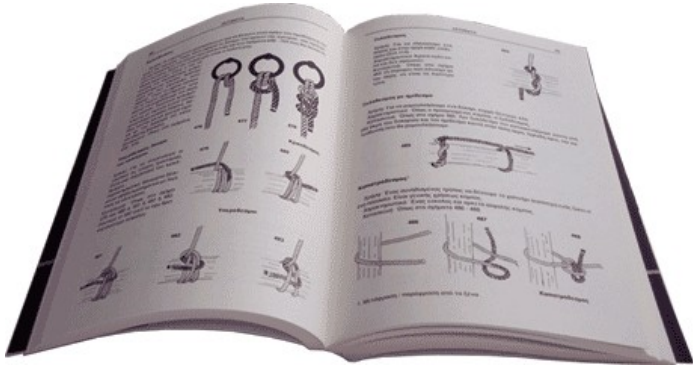
Why: mask changes only to create radical new system performance.



Sunlight-readable display



Book Replacement..



- Average book diagonal 8”
- 200 dpi 6 bit per pixel (equivalent to text)
- Reflective and transmissive
 - Black and white in reflection
 - Color with the backlight on (slightly lower resolution)
 - Roomlight increases resolution



ONE LAPTOP PER CHILD



Industrial Design

- **Fuse Project, Pentagonam, OLPC, Quanta**
 - **We want a machine the child will take care of**
 - **No black or white boring machines!**
 - **Robust – 50% thicker plastic than normal**
- **Design is about compromises**
 - **Wanted rubber bumper, so far we've been unable to identify a suitable material**
 - **Still working on this for future versions**
- **Iterate until done**

file:///home/silvia/LCA_talks/Wednesday/XO1%20Pictures/laptop-crank.jpg

file:///home/silvia/LCA_talks/Wednesday/XO1%20Pictures/Red_Machine.jpg

file:///home/silvia/LCA_talks/Wednesday/XO1%20Pictures/Yellow-front.jpg

file:///home/silvia/LCA_talks/Wednesday/XO1%20Pictures/Orange-rotate.jpg

ONE LAPTOP PER CHILD



November 2006:

1st laptop off the assembly line



ONE LAPTOP PER CHILD





ONE LAPTOP PER CHILD



file:///home/silvia/LCA_talks/Wednesday/XO1%20Pictures/B1-mikemcgregor-4-10.jpg

file:///home/silvia/LCA_talks/Wednesday/XO1%20Pictures/B1-mikemcgregor-3cropped.jpg

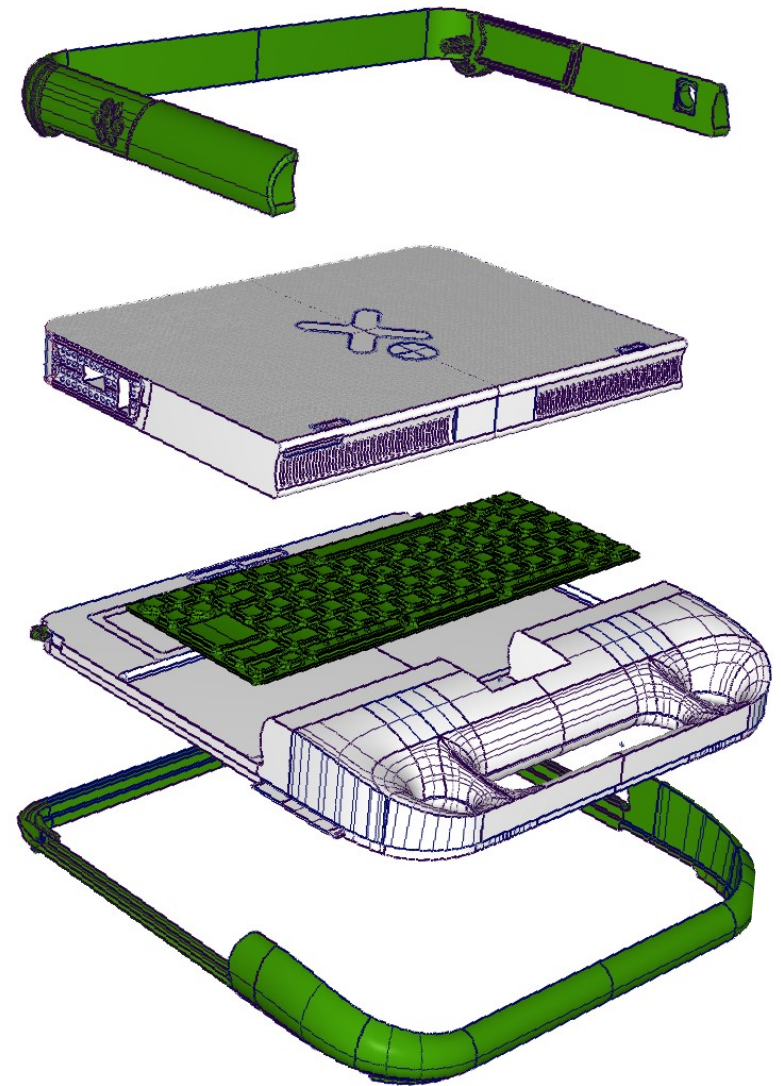
ONE LAPTOP PER CHILD



- **Early machines usually don't escape the lab**
- **BTest-1 Issues**
 - touchpad
 - buttons
 - screen angle
 - microphone
 - robustness
 - handle
 - antennae
- **Fixes in BTest-2 and BTest-3**

Mechanical Design

- **Safety first!**
 - *No hazardous substances*
 - *Rounded, kid-friendly design*
- **Moisture/dust/dirt resistant**
- **Extra rigid shell**
- **Internal “mainframe”**
- **3D connector reinforcement**
- **Replaceable bumpers**
- **Shock-mounted LCD**
- **Transformer hinge**



Environmental



vs



5 years of text books

- * deforestation
- * chemicals to make paper
- * distribution costs

1 laptop

- * RoHS compliant ++
- * 2W power (human recharge)
- * 5 year life (including batteries)
- * recyclable

ONE LAPTOP PER CHILD

Appropriate to appropriate



Transparency is empowering. Open-source software gives children—and their teachers—the freedom to reshape, reinvent, and reapply their software, hardware, and content.

System Software

- **Fighting software bloat**
 - *Focus on improved efficiency*
 - *Reduced CPU and memory requirements*
- **System security**
 - *Tempting hacker target*
 - *Theft resistance*
- **Secured firmware**
- **OpenFirmware now truly open – thanks, Sun!**
- **Linux Operating System**
- **“Sugar” User Environment**



LinuxBIOS / OpenFirmWare

- Much faster boot/operation than conventional BIOS
 - Allows us complete control – key to STR power working well
 - No ACPI!
- Potential to boot/install over the network
 - manual intervention is extremely tiresome both in manufacturing and in the field
- No royalty
- Kids can learn how computers **really** work

Software Applications

- **Journal**
- **Web browser**
- **WIKI / WP**
- **eBook**
- **Chat**
- **VoIP**
- **Email**
- **Logo**
- **Etoys**
- **Video support**
- **Music manager**
- **Audio support**
- **Multimedia**
- **Search**

Sugar Tutorial 11:00AM Thursday

- GTK+/Pango/ATK/Cairo stack
 - The same as gnome, the components are cross platform; applications may or may not be
- Python to tie it all together
 - Conventional applications can be embedded
- Using Presence as basis:
 - Web – follow me
 - Chat, Voice, Collaborative editing
 - Make music together: TamTam
 - Kids teach kids: teachers guide kids

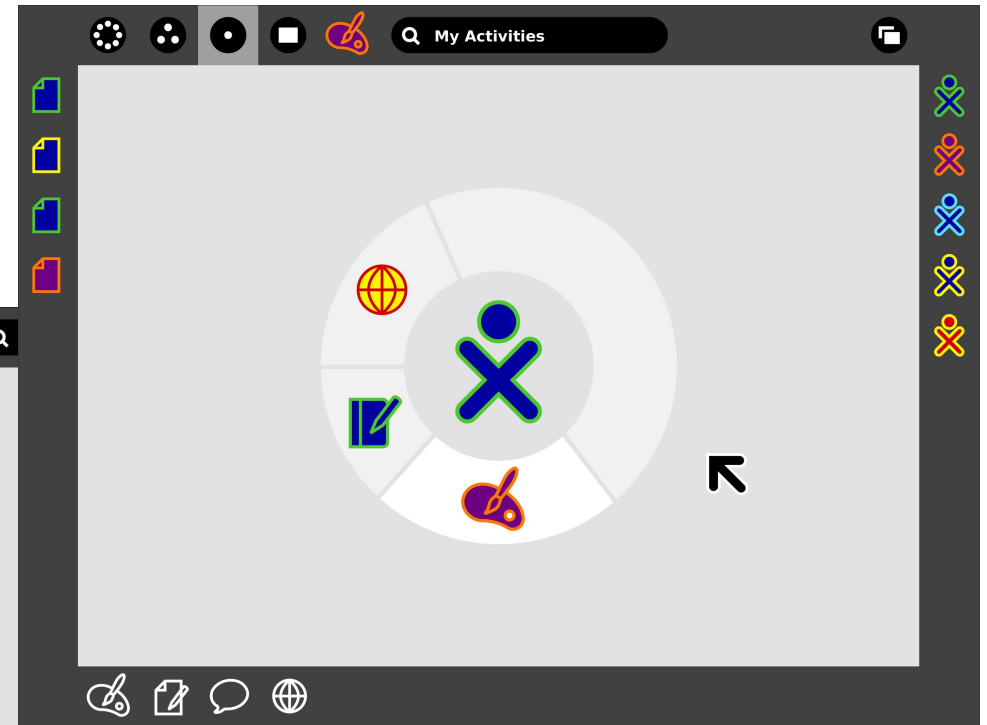
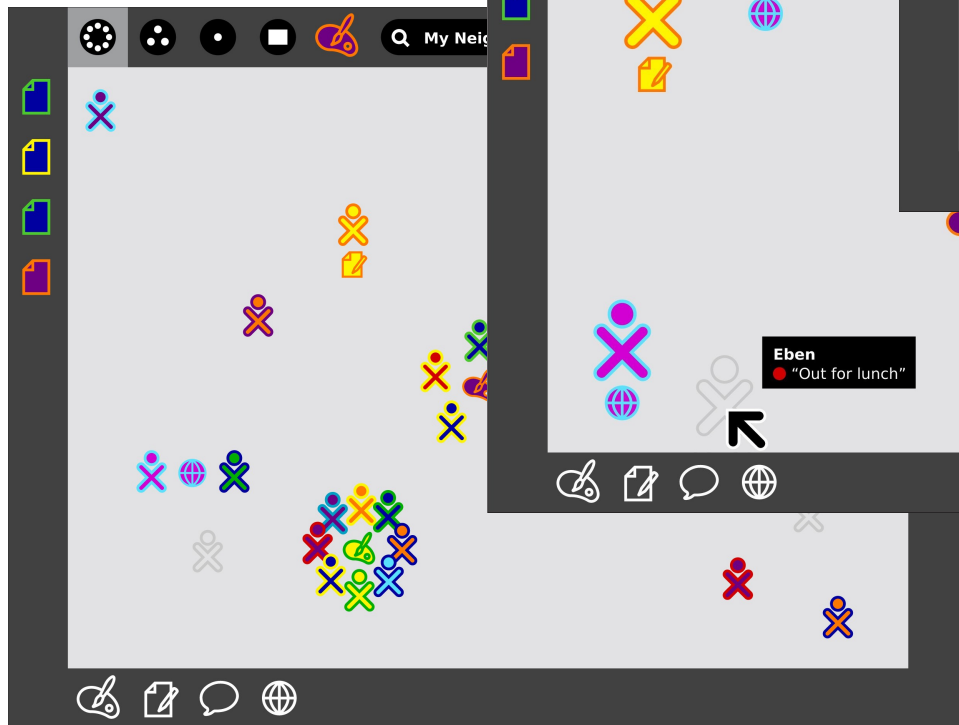
Collaboration, end to end, is key

ONE LAPTOP PER CHILD



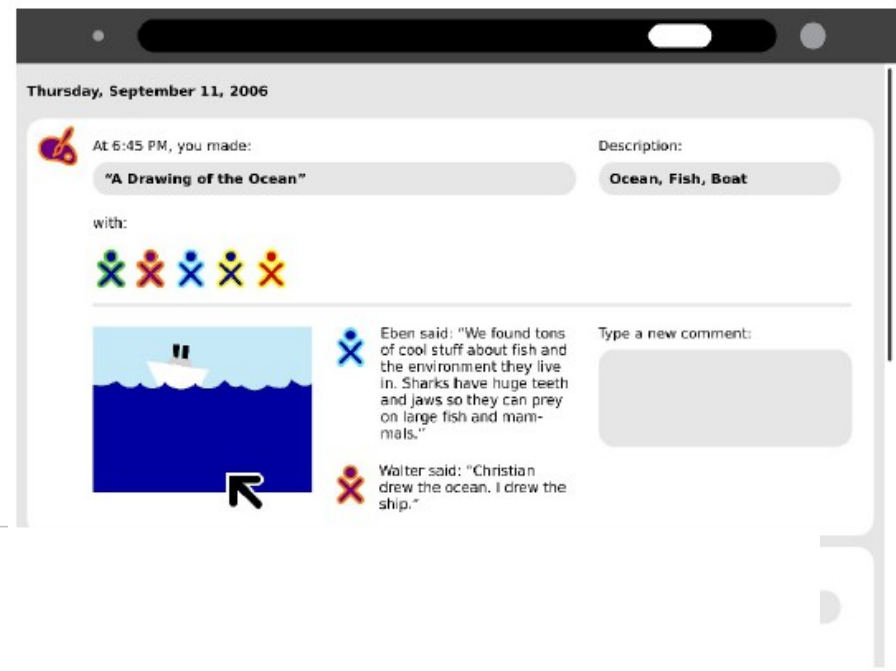
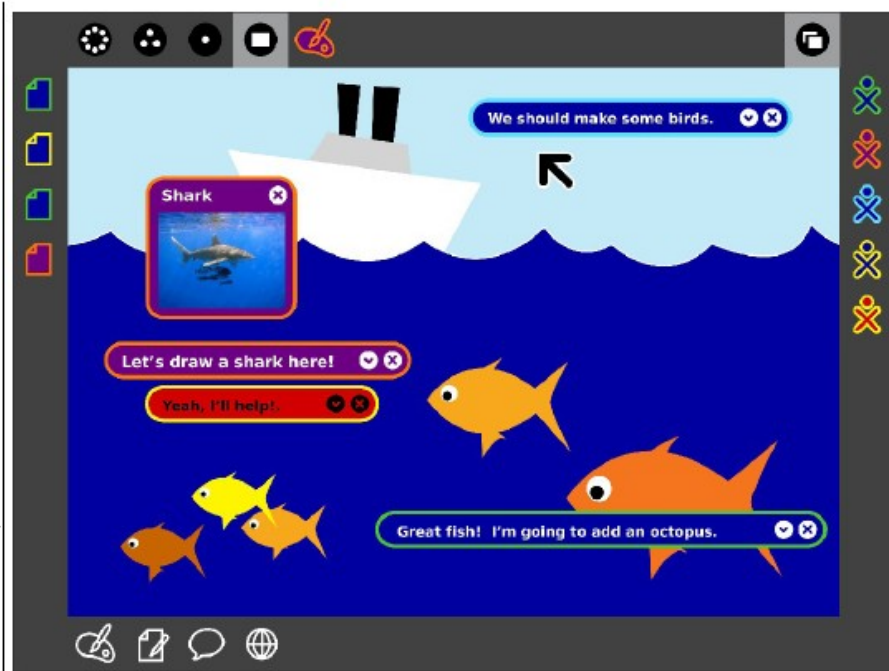
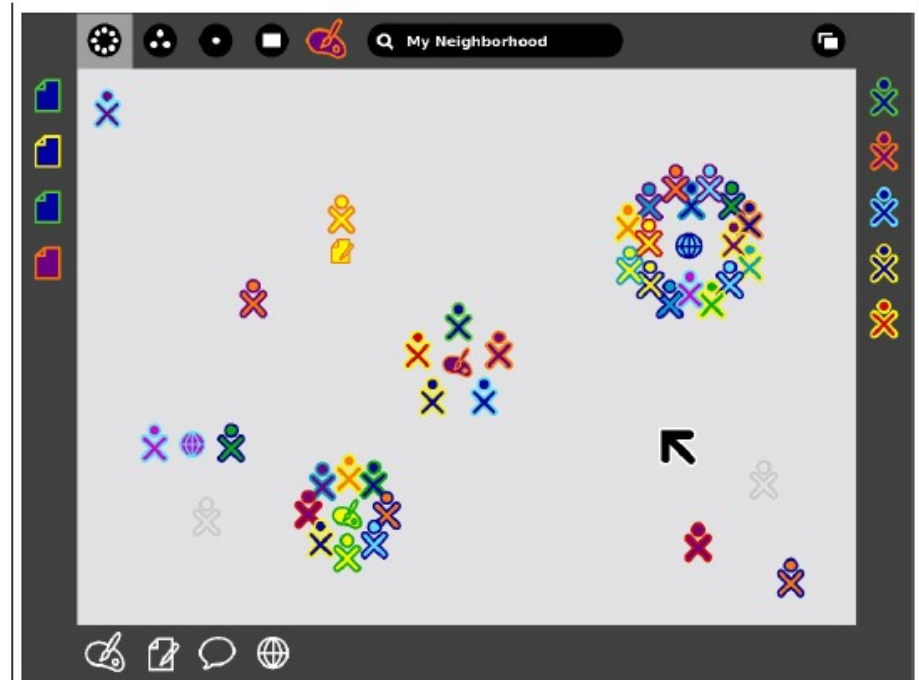
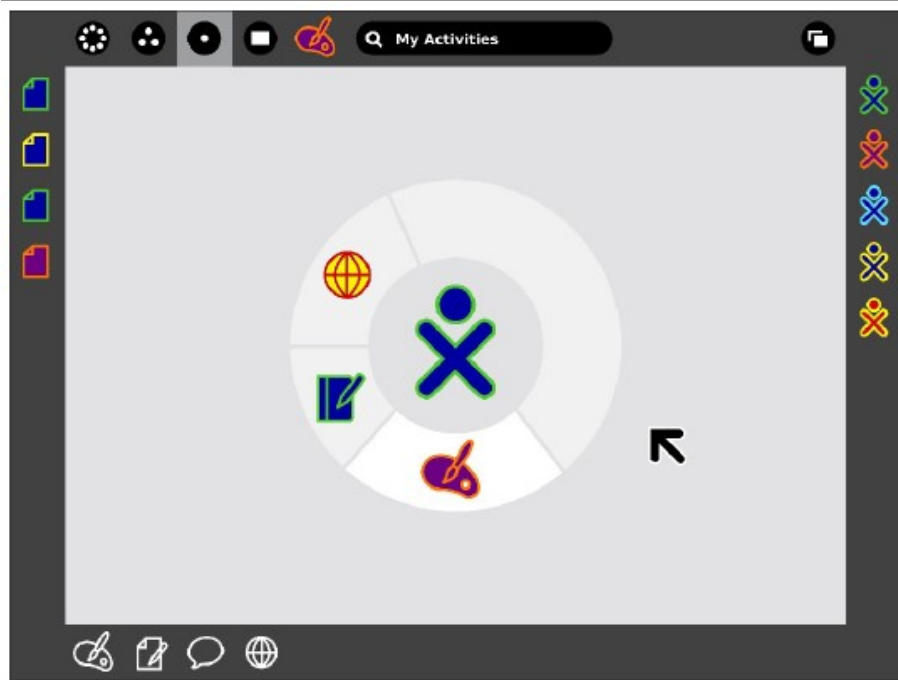
Zoom Interface

mesh view



ONE LAPTOP PER CHILD

Peer to Peer User Interface



Competition is Good

- If your application is big, slow and power hungry, we can't use it
- We often have many choices for any given tool
- Small is beautiful
- Simple is beautiful
- Open ended is beautiful
- Mantra: easy entry, no ceiling, collaboration

How You Can Help

- Help with memory usage and leaks – and the code usually runs faster, and uses less power!
- There is kernel work to do:
e.g. Power Management, OOM behaviour
- UI work is sometimes needed for power management and use on our screen
- Localization work is always essential
 - Our localization strategy will not scale!
- Educational software for children
 - We will host projects at laptop.org
 - Work together worldwide to maximize the amount of cool software for children

Memory Consumption

- Bloated applications & environment
 - We'll avoid using them
 - Many choices available to choose from
- Leaky applications
 - Fix those we care about – e.g. Firefox
 - Raise consciousness - already paying dividends – e.g. Federico Mena-Quintero
- Limits on flash size – compressions helps
 - Approximately 2x for typical code and data

End To End

- Most network services should **not** require infrastructure
 - Children (or you and your friends!) should immediately be able to work together, anywhere, anytime
 - With **no** infrastructure
- Systems should not require reconfiguration
- Servers as optimizations only
 - With the advent of zeroconf, mdns (i.e. Avahi), and anycast, this is within our grasp

TimeLine



- | | |
|-------------|--|
| Jan. 22 '05 | WEF announcement (intent) |
| May 2005 | Decision to be non-profit |
| Jun. 30 '05 | Brazil announces |
| Nov. 17 '05 | First prototype unveiled by Kofi Annan |
| Dec. 12 '05 | Quanta agreed to build |
| May 25 '06 | Developer boards |
| Aug 9 '06 | Display prototype works |
| Nov 15 '06 | Developer Laptop prototypes |
| Spring '07 | Education prototypes |
| Summer '07 | High volume mass production start |

ONE LAPTOP PER CHILD



Thank You!!!

Without *your* efforts over many years this initiative would not be possible.

Questions?

ONE LAPTOP PER CHILD

