Computer Demolition : Understanding about Technology

Version I-1.04

"Will American kids be Inventors in 10 years, or just operate appliances designed elsewhere?"
and, by the way,
"Whatever happened to the Kid who took Alarm Clocks apart to discover how they worked?"

These days the inside of an alarm clock consists of a microchip epoxied to an LCD display. There are no moving parts to examine. This trend has led to a hands-off, "I can't understand it" attitude towards common household devices.

Computer Demolition demystifies Technology by having kids disassemble and explore older Personal Computers. They begin to understand the Technology of today by Taking It Apart**!**

Principles and Objectives:

YOU HAVE TO DEMOLISH TECHNOLOGY TO UNDERSTAND IT.

KIDS LEARN THE MOST WHEN THEY ACTUALLY DO THINGS, HANDS-ON.

KIDS CAN COMPLETELY DISASSEMBLE OLD IBM XT-TYPE COMPUTERS , LEARN WHAT THE DIFFERENT PARTS DO, AND REBUILD THEM IN 1-1/2 HOURS .

Computer Demolition is an activity that we have been doing for several years. We start out by talking with the kids about "Why is Technology so Weird? Because It's Invisible!". We bring several working IBM XT type computers into the classroom and guide kids in disassembling them. The groups *must* be small! : 3 to 6 students per machine / mentor. (More about this, later.) Kids are encouraged to first observe the outside of the computer critically, finding that all the parts and connectors on the outside have links to the internal workings of the computer. We guide kids (trying not to touch the computer ourselves!) through disassembling the machine, understanding what the different parts and subassemblies are, how the computers were designed, and how the different sections work together. The kids learn what the job of the Microprocessor is, and the other main parts like RAM, BIOS programs in ROM, the diskette drive and power supply. Every kid gets their hands on the tools and the computer, taking turns at removing screws and parts. After the machines are completely apart, the mentors guide the kids in "making the simplest possible computer out of these parts, without the case". Starting with just the bare system board on the table, kids connect the power supply and speaker, and turn it on. The computer beeps and complains. The kids use the 'XT Error Code Sheet' and their own reasoning to figure out how the computer starts up and what it needs to run. Adding just the display card and keyboard allows the computer to start up in BASIC and the kids are guided to write a simple computer program on their 'minimum' computer. If time permits, they attach the diskette controller card and diskette drive, and watch the heads scanning the diskette and loading data into RAM so a program can run. Finally, they unplug the parts again, get the empty case and 'build an IBM XT' from scratch, usually in less than 10 minutes. The kids learn that technology is understandable if you really look carefully at one piece at a time.
NOTE: If you are involved with younger kids, see the complete Unit ***"How Does This Computer Really Work?"*** at http://homepages.together.net/~tking , which was written by Mary Alice Osborne for Kindergarten thru 2nd graders! There is great material to use with any age kids there.

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Equipment and Materials:

IBM XT Computers

Computer Demolition is based on using old original IBM "XT" computers[1]. These are still widely available at $0 to $10, especially at "Hamfests" or "Computer Flea Markets"[2]. The XT is a good machine to use because it is simple, mechanically well built, and it's "BIOS" software that runs automatically at Power-On time is good at telling you what it is doing, and what errors or missing parts it discovers. It also has the BASIC computer language in ROM, which is good for showing the 'minimum computer' running. The original XT came with a 360K 5-1/4" floppy drive, a 10 Meg Hard Drive, and an "Asynchronous Communications Card" (Serial Port). For use in *Computer Demolition* we almost always remove the hard drive and its controller card, as it adds unneeded complexity.To identify the IBM XT look for: (Front: Square silver label with black lettering "IBM Personal Computer XT", Back: Similar square label "IBM 5160", Back: 8 slots for option cards (NOT 5 like older IBM PC).

The appendices at the end of this booklet have detailed drawings of the XT, its System Board (Motherboard) and it's subassemblies, with pointers to explanations of the different parts. The XT has only *two* kinds of screws holding it together: the outer case has (up to 5) 1/4" hex head 8-32 screws and all the rest are 3/16" hex head 6-32 screws. See **Tools** below: we strongly suggest getting 1/4" and 3/16" 'nut drivers', especially for younger kids. If you haven't had an XT apart yet, now's the time to do it, before you disassemble it with kids!

So: The *IDEAL* machine to use is:

IBM 5160 XT system unit with:
- Hard Drive and Hard Drive Controller Card *removed*
- A CGA "Color Graphics Adapter" display (video monitor) card
- A Diskette Drive Adapter
- One or Two 5 1/4" Full-height diskette drives

— Appropriate Monitor: IBM 5153 or 5154 color monitors are best, to show Red/Green/Blue being controlled by the CGA Display Adapter. It is workable to use an IBM 5151 Monochrome display along with a "Monochrome and Printer Adapter". Various CGA or EGA type monitors from other manufacturers are fine too.

- XT type keyboard (AT and later clone keyboards won't work)
- *Optionally*: One or two other 'interesting' cards such as Memory or Async cards.

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[1]Other 'XT type Clones' can be used, but they often have disadvantages in poor mechanical parts, strange BIOS messages, lack of BASIC, and inconsistent accessories. There is a big advantage to going in with 2 to 4 machines that are totally predictable and well-known to you!

[2] You can find out where/when these happen in your area in several ways: (1) Get a bookstore copy of Nuts & Volts magazine, look in 'Events Calendar' (2) The Nuts&Volts website: http://www.nutsvolts.com (3) A local Ham Radio or Computer User group. (4) In the Northeast: http://flealist.senie.com

•**Power cords** for monitor and system unit and multi-outlet **extension cord** so you are independent of school room layouts.

•**Tools**: are simple: one each ¼ inch and 3/16 inch *Nutdrivers*. These look like a screwdriver but instead of a flat blade they have a recessed hexagonal socket like those on a tiny socket wrench. The screws on the XT *do* have straight slots for a conventional screwdriver, but younger kids (and me too!) find it a *lot* easier to use the nutdrivers because they don't slip sideways off the screw all the time. With 1st graders, doing this with a flat blade screwdriver is agony… for them *and* for the adults watching! One more optional tool: something to retrieve the screws the kids *will* drop down into the system board between the cards. A small magnetic tool, or a magnetized screwdriver is OK, or one of those little 'grabber' tools that come in the 'Computer Nerd Toolkits'.

•**Handouts and Props**: The only other thing *required* is the "XT Error Code" sheet. (This is available as an appendix to this document, and as XT_ERROR.TXT). When the kids first turn on the power to a bare system board and connected speaker, the only response from the computer is "BEEEEEEEP! BEEP! BEEP! (Long-short-short). Then we say "Well, what does *THAT* mean?? How could you find out?? How about some (...pulling sheet of paper out of box on the side) *documentation*?? That means a paper that tells you what all the XT error codes are! Look it up..." [Long-short-short means "Display Card Error", caused in this case by the missing display card that is sitting on the table, not plugged in!]

After you have the display card plugged in, and the monitor connected, the bare-bones system will display my all-time favorite error: "201 (Keyboard error) Press F1 To Continue!". Some of the kids think this is hilarious too: *"We can't press F1. We don't have a Keyboard!!"*

The other error you *expect* to get is 601 (Diskette adapter failed because it's not even *plugged in* yet). But you *can* hit F1 now, and in a few seconds the IBM BASIC computer language will pop up on the screen. Then you can coach the kids to write a computer program to see if their 'simplest possible computer' really works. Typically something like:

```
1 PRINT "OUR SCHOOL RULES!!"
```

After running this great program, you can add the complex second line:

```
2 GOTO 1
```

....Which loops and fills up the screen with their cool message. (Details of all this later).

Props: If you do an introduction to *Why Technology is so Weird* like we do, you'll need:
•a flashlight (preferably with 2 D cells, and easy to take apart to get the bulb and a battery).
•A cliplead (short wire with 'alligator clips' from Radio Shack et.al) or other short wire
•Possibly some cool picture of a complicated Ancient Invention[3], when talking about why "Real Smart guys from 2000 years ago, like Archimedes, could not explain this flashlight".

[3]I like the book ***Ancient Inventions*** by Peter James and Nick Thorpe (ISBN 0-345-40102-6) Page 225 shows Archimedes invention that grabbed the ships attacking Syracuse and overturned them.

2. School Contacts:

This will vary a lot depending on your circumstances and involvement.

Teachers

Our experience has been that the best primary contact is a ***teacher*** who wants the kids in the class to learn more about Technology and Computers. This may be a classroom teacher, especially in younger grades, or perhaps a Science teacher in Middle School. It is very important that you have a discussion with the teacher about:

- just what you are going to do
- why you "Just *can't* do this in only 45 minutes" (1:15 to 1:45 is best)
- what you need for a classroom setup
- how long you need to set up (about ½ hour minimum)
- exactly when and where you'll do this
- where you will park and how you'll transport the computers into the room (their cart?)

Administration: If you want a continued relationship with a school, it is good to touch base with the Principal. He or she is responsible for what happens in the building, children's safety, relations with parents, the community, and the School Board, the educational process going on in the school, and training and assessment of teachers. Best to try to catch them about ½ hour after school lets out for the day… Just tell them what you're interested in doing. Don't get too grandiose, especially at first. They've seen lots of flashes in the pan go by.

Most states have an association of Science teachers, or a 'Physics alliance' or something similar. Ask a couple of Science, Math or Computer Science teachers about what organizations are active in your area. If you want a LOT of work, do a presentation on your work to such a group.

How do you get time off from work??

To start out with, assume your employer is Education oriented, and wants to help out in the Community. What you are doing is Community Service or Education-Business partnership, right?? Assume you're in charge. Get an interested teacher or principal to write to your employer, asking for your help. Ask for time off *with pay*, during the school day / work day, for this important activity. Perhaps show them this booklet and tell them what you're planning to do. Ask the school to write to your employer thanking them for this wonderful opportunity they provided for the kids. If all else fails, take a long Lunch break, or (shudder), ½ day of Vacation. But do it. In 1995, for example, we got IBM to let groups of 4 Engineers / Technicians go out on company time into a classroom — over 100 times! Look at the H-P (Hewlett-Packard) website and read about their Mentoring program. Tell your company "Everybody who has good PR is doing Educational stuff!"

Getting ready to do Computer Demolition

We have learned a bunch of things *not* to do and some things *to* do, mostly the hard way over several years. And, of course, we're going to tell you all about them!

Note from Terry: Teachers, please excuse us for a minute while I talk to the Engineers and Other Nerds who hopefully will be doing *Computer Demolition*. They are, speaking for myself, a little strange and often clueless about all the Education stuff. Mary Alice is the Teacher, I'm the Engineer, and we actually work really well together, and have figured some of this out.

***DO NOT TRY THIS IN 40 MINUTES!* -** We know from hard experience that it is a *bad* idea to try to do this too fast! Many schools have 'regular' class periods of 40 to 50 minutes. They *want* you to Do Something in one period. Tough. Tell them they have to find a different time when an hour and ten minutes to an hour and 45 minutes is available. There are too many things that are important to finish without rushing: (1) Introduction, and discussion on "What Is Technology" (2) Groups disassemble the computers, discuss and identify the parts and functions (3) Groups assemble a 'minimum parts' computer on the tabletop, with no case, and debug the error messages they get, and finally (4) Groups build an XT computer from scratch, starting with an empty chassis, and test it. *Don't try this in 40 minutes!*

Student Inertia: Why you do not want any chairs - All of the activity during *Computer Demolition* takes place best when all the students are totally free to move around, go look at the computer from all sides, and to lean over it. Especially with younger kids, it's best to just sit on the floor for the (short) introduction. There is a real potential problem with getting kids to move around, once they get into the apparently safe refuge of a *chair.* Somewhere around 7th grade most kids acquire a strong suspicion that *someone is looking at them.* Once safely in a chair in the midst of their flock, getting out of their chair, especially if they are the first one, is somewhere between torture, middle school death and high school paralysis. In practicality, with the need for having computers on separate tables, with plenty of working space around them, chairs create a bad case of urban clutter. So we have found that one thing works wonders: *Get rid of the chairs before the kids come in!* Most school chairs are stackable, so we usually make 4 or 5 big stacks at the back of the room, put the 2 to 4 tables equally across the remaining space, and announce loudly if someone casts a desperate eye towards the back of the room, "*No Chairs!*".

Table space / Layout:
Make sure you talk with the teacher ahead of time to tell them what you need, and that you need to set the classroom up differently than a usual classroom, and that you need time to set up beforehand, and you have to lug a bunch of stuff in, and you have to *get the chairs out of the way*. For each 'station' (eduspeak) you need a large table (30" by 72" is a typical 'six foot table'). Position the tables around the room with one end about 3 feet from a wall. Visualize a crowd of 6 kids around each table, a monitor, chassis and keyboard on the floor at one end. Without people stepping on each other. Capacity runs from 4 tables / 20-24 students (small classroom) to 6 tables / 24-30 students in a large classroom. Of course, you may be doing only 1 or 2 stations depending on how many mentors you have available. Try to keep a larger open space in the center toward the blackboard end, for the introduction. Ideally you will start out with a horseshoe of kids in the

center area, milling around at the beginning while you're starting to ask them questions, and finally settling down, or sitting down. You can just say (even to dreaded Teenagers), "you guys can just sit on the floor if you want to..." If 3 popular kids sit down it will be like Simon Says. Otherwise they'll just stand. Don't worry about it.

Doing Computer Demolition

Apprehension about student contact:
If you haven't done anything like this in a classroom before, expect to be, honestly, scared! I've seen doctorates in EE who were petrified about going into a 5th grade. Just set things up right and it'll be easy... and you'll get better every time.

Making Initial Contact: The ideal situation is when you have had access to the room ahead of time to set up everything, and arrange the layout, and *then* the kids come in. This is easier in Middle School when kids often go to other rooms. Or try to get the teacher to arrange it so that you are right after a 'special' (Music / Art / PE) where the kids move around.

Don't dress up. Clean jeans would be good. Unless the kids are in 8th grade up, you're going to be on the floor, anyway. Freaky hair is good: works for me ;-)

With no chairs to sit on, the kids will mill right into your area. Immediately make eye contact and start talking to kids when they start coming in. Ask the teacher to wait until you have talked to the kids about what you're going to be doing, and they are starting to sit on the floor, before actually introducing you. Or skip the introduction, and wait until/if some kid asks you 'Who are you, anyway??' Start asking kids questions right away, during the initial confusion. This creates an immediate informal non-threatening atmosphere where kids will talk and not totally hold back. (More on how to start off, in the following sections).

Introduction:
Why is Technology so Weird??

Instructors Overview: This introductory section is intended to help kids understand why they may feel intimidated by "Technology". Most of us feel we can understand the world around us, just by looking at it and relating it to things we already know about, and thinking about and assimilating the information. This works for us most of the time. Kids encounter new things often, new school materials are handed out, and if they are 'smart' (good at assimilating new information) they understand them. *But*, the Technology-based things like computers, TV's and VCRs are different: often you can't understand them just by looking at them. This is unfamiliar ground, and often makes smart people feel stupid or discouraged. *Why is this?* Because Technology is Weird! It is based on things that you can't see, because they are *Invisible!* We will explore this area with a few examples, and aim at having kids understand this: when they encounter a Technology-based device, and don't understand it by looking at it, this is *normal!*

Dialog: Why is Technology so Weird??

NOTE: These dialogs are *not* a script; they are examples of the exchanges we have had that worked well, and are a guide to follow. Every group is different, and especially in the beginning it is important to let kids 'tell it their way' even if they are a little off track. You are setting the relationship up, and letting them know that you respect their ideas, and their 'answers' are OK.

INSTRUCTOR	KIDS / NOTES
OK, We're going to talk about Technology here. Has anyone here ever looked *inside* a TV, or something like that??	(Kids usually raise their hands) [Briefly point or wave at a kid to recognize them] (Let them tell this their way. Recognize a couple more kids, if that many are raising their hand).(Pick different people, boys *and* girls, not just the most vocal of the group. Look for the kid who is *almost* raising their hand).
OK, So what did you *see* in there??	(responses like): A lot of wires. A bunch of different stuff. Little rows of things, like a city.
All right. So, did you *understand* it?	(No..)
OK, I want you guys to understand *this!* I'm an (Engineer, Technician, teacher, whatever) and I've looked at this stuff a lot. When I open up a TV or a Computer, what I see is: *a bunch of wires and stuff.* Just like you do. I don't immediately understand it. Technology is like that! Let's think about the kinds of things we *do* understand. Things we can see and touch, like, say, a Mountain Bike.	(PROPS: If you can get a bike into the classroom, this is a good time to take it, and put it upside down on its seat and handlebars. Otherwise just talk about putting a bike in that position).
OK, there are a lot of parts, and this is kind of complicated, but we can *see* all of it. Let's (pretend to) turn the pedals, and watch the chain on the sprockets. Hey, the wheel goes faster than the pedals. Now, *how does that work?*	(Various explanations)
All right, lets talk about what's different about this Technology stuff. What if we got some really, really smart person from a long time ago, and asked them	

about this bike. I really like this guy Archimedes. He figured out a lot of really smart inventions. [Optional: show series of 3 pictures of Archimedes Invention that grabbed the ships attacking the port of Syracuse, and overturned them, or some other sophisticated *mechanical* invention.]	
OK, here's the point: If Archimedes were here right now, and we showed him this bike, and he turned the pedals and saw how the chain moved on the sprockets, do you think he would understand it?	[Yes....](Guide this response, as a last resort..)
Now, let's look at another thing, that looks pretty simple: A flashlight. (Turn it on, show that it lights up). Now.. if I just hold this here... the light keeps coming out. I don't see any moving parts. So, how does this work??	(Typically, responses like 'It's electricity', and explanations of a circuit with a battery, light bulb, connections).
OK, but something still bothers me. I don't see anything that *moves.* Let's take this apart, to see how it works... Here: *You* take it apart.	(Hand this to a kid, have them unscrew the battery end, take out batteries, maybe pass it to another kid, get them to unscrew the lens end, find and remove the light bulb.)
So, let's make this work. What do we need to do??	(Guide 2 or 3 kids to hold one D cell pointing upwards, and hold the bulb on top of it).
OK, so what do we need, to make it light up??	(A Wire.. etc)[PROP: a test lead with 'alligator' clips, or a plain wire with ends stripped] (Get them to see the bulb light up)
Ok, I have one question: *How Does That Work??*	(Typically: Electricity, circuit explanation)
OK, you guys know something about this. But I still don't see anything moving. What's in this wire??	(Guide, if necessary, to ATOMS and ELECTRONS)
Now, how about that smart guy, Archimedes. If he were here, could he explain how this light works??	(Probably 'No') [Ask: *Why Not*?]
Think about it. *Do this*: Look at your hand. Up close. What do you see??	(..Skin, tissue) [dirt?? :-))]
But what is your body made up of???	(Guide to CELLS if necessary)
Can you see any Cells? Why not??	(No)(They're too small)
All Archimedes knew was what other people had learned, plus what he could see and figure out. Back then, nobody knew about cells. Nobody knew about atoms, or electrons. They had lots of theories about elements and diseases, but they were wrong, because the answers were invisible. Technology is based on Science, and discovering the truth about things that are invisible. You guys know a lot already that *nobody* knew 2000 years ago, or 200 years ago, no matter how smart they were. You know that the world is made up of atoms and elements, and living things are made up of cells, and the stars are really far away and the earth rotates around the sun. But I want you to understand that this Technology stuff is *different* than other things. When you look inside a TV or a Computer, and you don't immediately understand it, you could think two different things: (1) You're dumb. or (2) Oh... That's that Technology stuff. It's always like that. I just have	

to slow down, and figure things out. And take things apart and look carefully at the pieces.	

You have to take Technology apart to understand it.

Now, we're going to have you take some more stuff apart, and put it back together. So I want you to slow down, and look at things carefully, so you understand how they go together. And, so you can put these computers together again, after you take them apart.	

Note: You may want to say, "In your groups, we're going to ask you to about some stuff you see, and ask you what you think is going on. What we're asking for is just a *conjecture*. That means a thing you think might be right, but it doesn't have to be. OK?**"**

Setting up Groups

NOTE: At this point you're about to separate into small groups and have each group go with a mentor to a computer. Make sure you understand ahead of time how you'll create the groups. If it is a large class, with multiple small groups, you may have asked the teacher ahead of time to define the small groups. If the class is fairly small, say 12 or so, we often just 'chop' off groups of 4 or so from left to right. Be decisive about this if you do it. Just say, "OK, I'm just going to chop off this group *here* (you 4 guys) , and this one *here*, and this one *here*." The groups are going *there*, and *there*, and *there*. Some kids will want to go with their buddies; it is better to say "No, we're not going to rearrange a bunch of groups right now, we have to start", and enlist the teacher to finish up this issue while you all get started on the Demolitions.

Disassembling an IBM XT

Instructors Overview:

This is the start of the real *Computer Demolition.* At the beginning, you need to keep emphasizing the mantra: *Slow Down, Look at things carefully, See what is around them, and how they connect to other things.* Keep asking questions: "What is this?", "What do you think this does?", "What is that connected to?", "What is holding that in place?", "How will you remember which way this goes together?" The *hard* part is really letting the kids do everything.
It's OK to point to things, and to model actions such as how to grasp a PC card and how to wiggle it upwards to free it.

Note: Looking Ahead - In this section we often spend quite a bit of time investigating the display, and the cable and connector going from display to display card. We do this because this is a good example of the kinds of things computers and electronics do, and it has a visible result. We follow this external investigation later *inside* the computer, as we investigate the display card as an example of an electronics device with chips, components and a printed circuit card. At that point we already have the idea that the function of the card must include controlling colors, and positioning the dots on the screen horizontally and vertically.

Dialog: Disassembling an XT

Part 1: Outside the Case

Note: Kids responses will, of course, vary widely. In fact one of our favorite things is that no two Demolitions are ever the same. The responses shown here are just examples of typical and/or desired responses. They are to guide you in getting a feeling for how things are going, and the things you need to guide kids toward to cover important material or keep the sequence going. But sometimes you will get a perfect question, or a perfect situation to bring in new information. Don't be afraid to grab this *'Teachable Moment'* and pick up the pieces afterward.

INSTRUCTOR	KIDS / NOTES[4]
OK, let's start out by just *looking* at this computer. We want you to notice that it *is* working. I mean, it *was* working, *before* you took it apart. Your job is to observe, *very carefully*, how this computer is put together, so you can put it back together, right. OK??	1st Grade: "OK. (Grin: teeth = 50%)" 3rd Grade: "Oh. Yeah! (Bounce.. Bounce..) 5th Grade: "We can *do* it!! Yes!!"[5] 6th Grade: "We are in serious trouble here!" 8th Grade: "Did you bet any *money* on this?" 10th Grade: "You are not supposed to smoke *anything* in this building"
Now, you've seen most of this stuff on the outside before. What's this called??	(Pointing to MONITOR, atop System Unit). Kids: "The Display / Monitor / TV / etc"
Right. Today, if you look in a magazine ad, they're usually called *DISPLAY*s.	
All right, what do you call this... whole thing, here? (Points to System Unit).	Kids: "The Computer / Case / Box / Frame"
Well, most computer companies call it the *System Unit*. Or sometimes the *case*.	
Now, what's *this* part? (Points to front of diskette drive in system unit).	Kids: "The Disk / disk drive / floppy / door" (If necessary, open diskette door, look at diskette, guide a little. Say "We'll look more at this when you take it out of the system unit in a few minutes")
OK. What's *this*? (Points to keyboard)	Kids: "Keyboard".
Sure. Now, the important parts: let's look carefully at the *back* of the computer and see where this stuff plugs in.	Kids: (Come around to the back of the table, and start looking at cables etc).
OK, where does the *Display* plug in? Follow the cables.	Kids: (Find one power cable, one signal cable going to *Display Card* in System Unit.)
Let's slow down, and think about this. What's going through this cable??	(You have a program running that displays blocks of RED, GREEN and BLUE, and some WHITE letters. You turn the display around so everyone can see it.). Kids: "Pictures / Letters / Colors / ?? "

[4]These are our favorite actual responses, so far.

[5]We definitely recommend you do your *first* Demolition with 5th graders!

First, what really is inside this... black thing.. here?	(Flexing monitor signal cable) Kids: “A wire?” “Wires”
What’s the difference between a *Wire* and a *Cable*?? This is a Cable, with more than one Wire inside it. This one has 8, I think.	
All right, let’s think about this. What do we have going through the wires in this cable? You unplug the cable from the back, and let’s look at it.	Kids: (Unplug the cable from display card)
Oh, what happened to the screen??	Kids: “It’s all white, now”
OK, look closely at the connector on the cable. What do you see??	Kids: “Little needles / pins / ?? “ Guide to ‘multiple connections’
All right, there are, uh, 8 pins on this, 8 connections. Actually there can be 9 but many plugs only have 8 in here. How come we need more than one??	Kids: “?? / Different colors / “
Right. I happen to know that there’s one wire for RED, one for GREEN, one for BLUE, one for brighter and dimmer, and a couple others. What *other* things might we need?	Kids: (Various conjectures)
OK, let’s think about this. How does the display put letters and pictures on the screen?	Kids: (Various conjectures)
Well, let’s look at the display. Plug that back in again. OK, the display *SCANS* across the screen with a series of dots called *PIXELS* . The dots can have the Red color turned on, or Green, or Blue, AND more than one color at once.	(View the display)
What color do you think we get if Red and Blue are turned on together?	Kids: “Purple!”
Right. Like this part (points). Now, what if Red, Green and Blue are ALL on together?	Kids: (Various: often “A yucky color!” or “A dark color”)
Well, this is *different* than paints, which subtract colors. Light *adds* colors. So all the colors add up to *white*. You’re not used to that. Like Red plus Green adds up to..*Yellow!*	Kids: “Weird...”
But the important part is, what *signals* does the *computer* have to send to the display through these wires?? The other kind of thing is *where* to put things on the screen. Let’s make it start a little sooner on each line.	(Use the arrow keys to move the displayed screen to the right, then left. At far left, the display should lose “horizontal sync” and the picture should break up) Kids: “Oooh. It got all wiggley../ etc. “
OK, one of the signals in the cable tells the display when to start each line. Right now the start of the line is at the wrong time, and the display is all confused. (Us *OLD* people	(Move it back, into “sync”)

remember when TV's used to do this, pretty often). OK, that's better. The signals the computer sends out have to be *right*. Now, look carefully at where the display plugs in, 'cause soon we'll follow where it goes *inside*.	
All right. This is important! If we're going to take this computer apart, what should we do *first?*	Kids: "Turn it off! / Unplug it."
Right! Now, look at where it's plugged in, and where the power cables plug into the display and system unit. You guys who unplug them, remember where they plug in.	Kids: (Unplug cables)
OK, the display is all unplugged. I'm going to put it out of our way. We are not going to take it apart.	(Put display on floor, end of table)
Now, where does the keyboard plug in? Look carefully at the plug after you unplug it. How many pins does it have?? Remember that it has to be pointing the right way to plug back in.	(5) (Put keyboard at end of table, or next to display).
OK. Everything is unplugged. Now, what holds the system unit case together??	

Dialog: Disassembling an XT
Part 2: Taking off the Cover

Instructors Overview:

From here on, kids will be using tools and removing parts. Tell them again that they will be taking turns, and that it very important for them to see how the parts go together. Suggest that they also think about the *order* in which parts are removed, because some parts are hard to reach when others are in the way. Make sure that everyone takes turns. The objective here is to keep thinking "why was this made this way?" with a emphasis that "some people had to decide how this should be designed and made. Why did they do it *this* way?**"** Ask if they noticed that all the connectors that plug in the back are *different*. Could they ever be plugged in *wrong*?? Ask them why there are unused slots on the system board, and what kinds of things could be plugged in there? Why are there two power cables for disk drives, but only one diskette drive? How about that empty space in the front of the case?

INSTRUCTOR	KIDS / NOTES
All right, let's look at this. The top is white, and is one piece, and the bottom is black. What holds the top in place??	Kids: "These things / screws / bolts"
Notice that there are two sizes of screws. The	Kids: "Yes. These.. 2 / 3 / 5"

bigger ones hold the case on. Do you see them? How many are there?	
There are 5 places for screws but we may not have them all here. *Real computer nerds* only have one screw holding their cover on because they take it off all the time!	
OK. Tools. I happen to have these thingies.	(Show *nutdrivers)*
Now, look closely at these for a minute. They look like screwdrivers, except they're different.	Kids: "They have little .. / hexagons / nut shapes / allen wrenches! / ends"
Right. Now look at the screws. What are they like?	Kids: "They have 6 sides too / but they have slots too/ etc. "
You could use a regular screwdriver, but these are better because they don't slip off the screw all the time. Now, we'll take turns with these.	(One ¼ " nut driver to a kid, who starts on a case screw)
Now, one little detail! How do you remember which way to turn the screws to loosen them??	Kids: "Left Loose. Right Tight!" or "Lefty Loosie, Righty Tighty" in the younger grades[6] (You need to keep watching for wrong way)
We need some place for these screws. Here's a paper cup. Egg cartons are good too.	(Take turns until case screws are removed. Watch for kids trying to remove power supply screws. With *only* the ¼ " driver they can't, though!)
OK, cool. Now this can come apart. Which way do you think the top moves?? (Kids name), why don't you get in the front and pull that case towards you. But go slowly!	(Guide to FORWARD. You may find it necessary to reach in front and apply pressure between the top cover and diskette drive to make the case 'easily' start coming off.
Notice, when you get it almost all the way off, it stops. Now you have to lift your end UP a ways and it'll come off. OK.	(Point out the bracket that makes this necessary. Put cover on floor out of the way. You won't need it for a long time!)
All right, let's just look at this for a minute. What *is* all this stuff??	Kids: "Ooh. AH.. look at all the stuff! "
OK, lets have some names for some of these things. Remember, conjectures are OK.	Kids: "Wires? / Batteries ? / Little rows of houses / etc. "
We'll figure things out. Let's see what the different areas in here are, and what they go to on the outside.	(Show the diskette drive is a separate piece, the power cord had been plugged into the power supply box which is another separate piece. Note the feature cards plugged into the system board.)
Now, how about the display, with the Red, Green and Blue? Where did that plug in??	Kids: "Here. That little (connector) with the 9 pins"

[6]We're collecting these! Please send new ones you encounter to tking@together.net

Dialog: Disassembling an XT
Part 3: Feature Cards

Instructors Overview:
The display card is used as an example of a functional part of the computer. We already know what it does (R/G/B/HSync/VSync) so now we can look closely at a printed circuit card, and what electronics parts look like, close up. Reiterate that they (and you) can't tell exactly how these things work just by *looking* at them, because most of what they do is *invisible.* Show them a copy of the spec sheet from a 7400 TTL Chip (URL?) and find one on the CGA display card. Say that you could understand the card *if you had the right information.*

INSTRUCTOR	KIDS / NOTES
Ok, let's follow some stuff we already know about. Where did the display plug in, before?	Kids: Looking at back, finding connector.
Now, look very closely and find out exactly what that is connected to.	Kids: Tracing connector to *Display Card*
All right, this thing (card) is a plug-in part. We know it controls the display. Look carefully and figure out where it begins and ends, and what is holding it in.	(Guide to: Connector - bracket - card - screw on top of bracket)
Now, notice: there are 8 places a card like this can plug in. Do you think it matters which place it is plugged in?	Kids: (Yes / No)
This computer has all 8 connected together the same. This is called a Bus... like a bus line with 8 stops on it. Look at the wires running thru all 8 places.	
OK. Take it out so we can look at it. Oh, you need the other size nutdriver. You'll all have a turn to take some other stuff out, too.	Kids: remove screw.
Now, what direction does this have to move to come out?	Kids: "Up, I think..."
Right. You have to pull it up, but also wiggle it. That's true of almost all connectors. Be careful grabbing onto it, there are sharp little wire leads on the circuit board.	Kids: (Try to pull up card. Often it's hard).
Let me show you how to grab it. One hand on the front end, one on the back. Pull up on the front, then the back, to wiggle it. Now, you do it.	Kids: (The card finally loosens up, comes out).
OK, let's look closely at this. What are all these things??	Kids: "Little squares. Like houses in rows. Little yellow things. "
What was the part that plugged into the motherboard??	Kids: "Oh, this part.." (Card edge connector)

Right. What does this look like it's made of?	Kids:" Gold!"
Yep, It's real thin gold, but it's gold. That's so it makes a good connection.	
Now, where did the display plug in again??	Kids:"The connector, here"
Notice how its pins go around a right angle. What do they connect to??	Kids:"They go into the .. thing.."
OK, what are all these??	(Point out printed circuit traces)
Notice they go mostly *this* way, on the top, and *this* way on the bottom. What do they do?	Kids: "They're like ... *wires* "
Right, they're the *wires* that connect the *chips* together, and to the *connectors*. Now, if your job was to make this display controller, and you had to put on all these wires... how many do you think there are??	Kids: (Various / hundreds)
If you had to use regular wires, and take, you know, the plastic insulation off each end, and hook each end up, and get them all in the right place... how long would that take??	Kids: "A long time / that's hard / etc. "
Now, how do you think they made *these* wires?	Kids: (Various: "A machine", "A copier")
Think about it. If you make a really good drawing, and you want to give a copy to 3 people, do you draw it all over again??	Kids: "No, you go to, like.. one of those machines, and a light shines all along it, and it makes copies" (etc)
Right! This is done like a photograph, or a copy... with light. But somebody, first has to decide how to hook all these parts up, and has to make the pattern that connects them.	(Trace a few wires, showing that on a plane -- In *FlatLand* -- wires can't cross each other, so they have to sometimes go through the card to the other side, and then back up.)
So, remember our display? What kids of things do these chips do, anyway?	Kids: "well, somehow they have to do Red/Green/Blue and where to start and stuff".
Yep. And how come we can't tell just which parts do what, just by looking at them??	Kids: "Cause it's *invisible*.."
But, if we look real closely, and get *more information*, we could start to figure this out.	(Optional detail: Show portion of the CGA card schematic, with the signals to the display connector, or an LS244 data sheet)
So, we can get *roadmaps called schematic diagrams* when we really need to know just what is hooked up to what.	
OK, enough of that. Let's take some more of this stuff out! Look at this next card. What is it hooked up to??	(Guide to find cable connecting diskette controller card to diskette drive.)
This is a Cable. But it's *flat*, right? What do you think this kind of cable is called?	[Ribbon Cable]
About how many wires do you think are in this cable?	[34. This is an easy way to have lots of wires. And notice the connectors are just clamped on all at once. There aren't 34 jobs to do]

Now, look closely. How are you going to remember which end of this cable went where??	(Guide to notice the twisted part near drive A:, or the connector spacing.)
Push on the connector, first on one end, then the other. See, it will slide off. Notice how it has a little slot so it can only go on one way!	(Put cable off to end of cable)
Now, take out that disk controller card. OK. See, it has similar chips and printed wires, and also a connector to the disk drive.	
Now, what is holding in the disk drive??	

Dialog: Disassembling an XT
Part 4: Speaker and Diskette Drive

Instructors Overview:

Now, you have to move along, getting the machine apart. You *really* didn't want to do this in 50 minutes, right?? This might be an OK time to find a second 3/16" nutdriver, and have two kids taking screws out at once...

INSTRUCTOR	KIDS / NOTES
Look at the disk drive. What are it's boundaries?? Which direction will it go to come out?	Kids: "It's this... part" (Circuit board atop drive. (Note: kids will want to remove obvious screws on top, holding circuit board. Say "No, we want to take the drive out in one piece. What's holding it in??) (Guide: Disk drive comes out like a *drawer*)
OK, 2 screws and it's loose. But there's one more cable. It's hard to see, because it plugs in from the bottom of the circuit board. And it's the *hardest* connector to get loose in the whole machine!	(Guide to disk drive power cable / connector. Show how to grasp the sides of the connector and *wiggle* and push down. If necessary, help push on one side. These can be tough!)
OK, carefully keep pulling it out.	Kids: taking it out, turning it over: "Cool! Look at the little wheels and belt."
Think about it. This is a separate part.. A subassembly. If this didn't work right you could replace this whole part.	
Now, a few more parts to go. What is this part? Have you seen one of these before??	(Points to speaker. Guide to speaker / radio / walkman / sound etc..)
Look closely. It plugs into the motherboard. See which way to unplug it. Remember where that is, because we will need to plug it back in soon. See where it is screwed in. One person hold the speaker, it's kind of hard to unscrew because the screw goes into plastic.	(guide to removal. Put aside on table)

Dialog: Disassembling an XT
Part 5: Power Supply / Motherboard

Instructors Overview:

Again, you can use two nutdrivers here, on the 4 holding in the power supply, as well as the motherboard. Pay particular emphasis to the motherboard power connectors, making sure the kids are careful with them. You will end up with the motherboard on the table, and put the case/chassis aside.

INSTRUCTOR	KIDS / NOTES
All right, what's this silver box, here. What did it hook up to?	Kids: Power cable from wall.
This is a *Power Supply*. It changes the electricity coming from the outlet to voltages the computer runs on, like 5 volts and 12 volts. What does it say on the Yellow sticker.	Kids: Zone Dangereuse, GeFahrenZone, etc.
5 Languages tell us not to take it apart. We'll take the hint. Lets just take it out.	
OK, look carefully at where power comes into the motherboard. You have to be careful because the connector pins could get broken. Look at the connectors, as you pull them straight up and off. See, they don't go right on the top? They go off to the side a little. Good.	(Guide to unplug power connectors. Closely supervise when they plug them back, in...)
Now, you guys take out the power supply. See what's holding it in? Notice you have to slide it back a little before it will lift out. Remember, you'll have to put it back that way	(Guide to 4 rear screws if necessary...) (Guide to slide back, lift out.)
What's holding the system board in??	Kids: "These screws". "These little white things"
The screws are all you need to take out. We'll see how the little white things work when it comes out.	(Guide to slide motherboard 1/2" out, to be even with the edge of case. Then lift slightly and slide out.)
See, it slides into place on those little white buttons. Then the screws hold it there. You have to be careful when you put it back in that the buttons slide in the right place.	Kids: "Oooh. look at all the (printed) wires.
We're going figure out what the different sections do, in a minute...	

Building the simplest working computer

Instructors Overview:

This takes some guidance. Kids usually want to connect too much, like the disk drive right away. Emphasize the *absolute minimum* to have a working computer. You will start with just the system board, speaker and power supply. Have the kids think like a computer, that is waked up by applying power, and just starts to look around and check itself out.

Dialog: Building a Minimum Computer

INSTRUCTOR	KIDS / NOTES
OK, now we really have to look at this system board closely.[7] Or sometimes it's called the Motherboard... and those other ones that plug into it are Daughter boards. People are always trying to make Technology seem more Human.	(Get on both sides of the table, so everyone can see well)
We're going to try to make this work in a minute, but we have to think about what it's going to do. This is where the heart of the computer is, the Microprocessor. Which chip do you think that is??	Kids: "One of the bigger ones?" (Guide to finding the 8088. Notice if it's an INTEL or not.)
OK, now we have to think like a computer. Just following the directions in a computer program. When you turn the power on, you wake up the Microprocessor. It looks in the usual place, and starts running a program called POST. What do you think that means? And where IS it? We don't even have a disk drive...	Kids: (Some conjectures), "Somewhere on the motherboard"
POST means: Power On Self Test. The computer runs a program that is always here, on the motherboard. That program is a buncha' bits, in one of these chips.	(Guide to ROM BIOS chip: See Drawing)
All right. There's the Microprocessor. There's the Read Only Memory with the Power On Self Test program in it. Now, the computer needs some memory it can write things into, and later read them back. That's called RAM for Random Access Memory.	
There's a bunch of RAM on this board.	Kids: "Must be all these rows of chips that are

[7]We used to think we were really cool, and high-tech when we got down to a System Board! A couple of months ago, when we got to this point, a 5th grade girl said, "Hey! This looks like an INTEL Commercial!". Even the mass media gets into our act, now...

Where is it??	all the same"..
Right!. OK, the computer is going to wake up when you guys turn the power on. Yawn. Blink. See if it feels OK. If it's unhappy, it will probably beep at us, so hook up the speaker.	Kids: (Hook up the speaker, noticing it only can go one way).
Good. Now, how about Power?	Kids:" Get that Power Supply thing". "Are we going to get Electrocuted??"[8]
Carefully put the power supply next to the system board, so the power connectors line up. Now, be careful. The connectors are funny: they don't go right on top, but off to one side.	(The 'remover' should know these by now, but watch this closely. If necessary, model placing the connector in the right position.) NOTE: The two connectors should be almost in the right place, with stiff wires pretty much positioning them. MAKE SURE the "black wires of the two connectors are together in the center". This is the only 'fatal' error that can be made.
All Right. System board. Speaker. Power Supply. All we need to start. Wake it up!	Kids: Turn on the power switch. If there is nothing but a resounding 'click' because they forgot about the Power Cord detail, just stand there and say "Hmmm". Eventually, ask "Where does the power *come from*, anyway?"

[8]*SAFETY*: The only dangerous voltages are *inside* the power supply and the monitor. Point out the label on the power supply that tells us not to open it up, in 5 languages! We Don't. The PC power supply puts out +5 volts, +12 V and -12V, and is current limited. It is usually considered "Intrinsicly Safe". Even IBM Safety (that Bastion of Nervousness) agreed this was OK. Just tell the kids to be careful not to short anything out with a nutdriver, jewelry etc..

Debugging the minimum computer

Instructors Overview:

The intention here is to have the kids "Think like a computer" as it wakes up and checks itself out. If you're so inclined, you can mimic a waking computer blinking, feeling it's face and arms and legs, checking what it's supposed to have, etc.. The "XT Error Code Sheet" has the Beep Codes, which are all you have until the display is working. Then it has the numerical error codes like 301: Keyboard error etc.. At the end of this section, you should have the System Board, Power supply, speaker, display card (connected to display) and keyboard connected. You should end up running a 2 line computer program in BASIC. This is not hard, but you should practice ahead of time so you know how to do LIST and RUN etc.. As the computer starts up, you can point to the parts that are active and do a play-by-play: "Power supply, Microprocessor, ROM with POST program, RAM, Speaker, Display card, messages as RAM is tested bank by bank: 64K, 128K 192K, 256K, Done ! Now, where the heck's the floppy drive? Not Home. OK, forget it, go to *BASIC!***"**. End this section by saying something like "OK. You have 10 minutes left to build an entire IBM XT computer! Unplug this stuff from the system board, get the empty case, and get started!**"**

Dialog: Debugging the Minimum Computer

INSTRUCTOR	KIDS / NOTES
Ready? Let's watch and listen closely, when you turn the power on. (Optional: play-by-play)	(You should expect: Switch click / Power supply fan starts / 4 seconds silent / "Beeeep, Beep, Beep" that is: long-short-short Kids: "The fan! Oh, it beeped"
Oh good! It's alive. It's trying to tell us something.	Kids: "It went beep, beep"
Now, turn it off, and then on again. Listen closely. What is the pattern??	Beeeeep. Beep. Beep.
How do you know what that's supposed to mean? You need some more *information*! Like this... XT Error Code sheet.	(Whipping out the Error codes sheet...)
OK, look at this and find that code.	Kids: "Mumble, mumble, 1 Long and 2 short beeps ! Here it is. it says "Display".
Think like the computer. Wake up, start Power On Self Test. Hey, how does it know what to test??	Kids:"It knows what it's supposed to have"
Well, partly. But remember this little switch here, on the motherboard? Actually, It's 8 little switches. One of the first things the microprocessor does is look at those 8 switches to see which ones are turned on. It tells it how much memory, how many disk drives, and what display it's *supposed* to have.	(Guide to look at the switch, and notice that switch 5 is ON, switch 6 is OFF, which means "you should have a 80 character wide Color display")

So, it's looking for a 80 character wide Color display. And it's finding... *Nothing! What does it do? Complain!! Beep!! Tell somebody. Somebody do something!!*	(Guide to finding the display card, plugging it in *(power off first*!) and connecting the display and powering it on.[9]
OK, let's try this again, with the display plugged in!	Kids: (Turn on the power, watch) (This time, the display first goes black That's Good!: power is on the display card. Next, a plain white cursor shows. That's Good! The display card knows 'where to start a line'. Finally some numbers appear: That's good!.)
Let's watch these numbers. What do they mean?? first 301 then counting numbers, up to 256 then 601 then "ERROR. PRESS F1 TO CONTINUE"	Kids: "We'll look it up. 301 , mumble, 'Keyboard did not respond or had a stuck key'. 601, mmm, 'Diskette diagnostics failed'. Press F1... *Wait!! We can't press F1!! We don't have a keyboard!! (laughter..)*
My favorite error message of all time! OK, get the keyboard. Power off. Look carefully at how the plug goes in. Try it again.	Kids: (Plug in keyboard, power on again....)
(Play-by-Play): Ok, who's on first? Power on, look at the switch, reset the display, OK, reset the keyboard, OK, -- No 301 --, testing RAM, 64, 128, 192, 256 OK!, now reset the disk drive, oops!! Nobody Home!! Put the error message on the display. Wait for someone to *help me*!! Or press Enter and try to continue.	Kids: "OK, 601 Diskette error. We better hook up the diskette".
Well, let's not, yet, anyway. Why don't you press F1 and see if it will continue??	Kids: "OK, push F1"
(Resuming Play-by-play): OK, they pushed F1.. try the diskette again, maybe they fixed it.. nope, still bad. Time to give up and start up BASIC.	(IBM BASIC appears on the screen)
OK, "IBM Personal Computer BASIC" What is it??	Kids: "We don't know. / BASIC is programs / etc. "
Well, BASIC is a computer language, for writing programs. A couple of guys down the road at Dartmouth created it so beginners could write computer programs. The "B" in BASIC stands for "Beginners". Think we can write a small computer program??	Kids: "WE don't know how / Sure! / My brother writes programs in BASIC / etc"

[9]It's best to turn the display power on early and *leave* it on, even when powering the system unit up and down. That way you get to see the first POST messages without waiting for warmup.

Al right, I'll help you. Think like a computer, right? All it does is what programs tell it to do. Let's tell it the first thing to do, like this: 1 PRINT "	
Wait a minute, what do we want it to print on the display??	Kids: "Hmmm / OUR SCHOOL RULES! / I don't know "
(Take reasonable suggestions, or quickly go ahead to "Hello World" the default simple program)	(Get kids to type this part, unless it's a early grade, and no kids know the keyboard).
1 PRINT "OUR SCHOOL RULES ! "	
OK, There's our wonderful 1 line program. If we RUN the program, the computer will look at these instructions. Now, you type in RUN	(Kid types in RUN <Enter>) (The program prints the line. NOTE: it is good if you sneakily type CLS which clears the screen, for less clutter.
Well. That's pretty boring. I have an idea for one more line. Tell me what you think this will do: 2 GOTO 1 Now, think like a computer...	(Guide kids to do 1: Print, 2 GOTO 1, now at 1: Print, GOTO 1) If they don't get it, say "OK, just type RUN and see what it does). (Screen fills rapidly with lines of Print)
Even this little computer can do instructions over and over again, real fast...	
OK! We have a minimum computer. But we can put things IN, get things OUT, write programs and run them. Everything else is just added conveniences. Like not having all your programs disappear, when the power is turned off.	OPTIONAL: Have kids hook up the diskette controller, ribbon cable and diskette drive (on its side so the belts and head movement can be seen). Reboot and watch as the motor starts, heads scan the diskette, and the program is loaded into RAM and run. Also say,"There are lots of good parts on a disk drive like this. You could learn how to make other things out of them, like robots."
OK! You guys have 10 minutes to, build a complete IBM XT computer from scratch! Turn off the power, unplug all this stuff from the system board, get the empty case...and get started!!	

Building an XT computer from scratch in 10 minutes or less.

Instructors Overview:

At this point, the kids know what all the parts look like and how they hook together. There are a few mechanical details to watch as they start to build the computer. Guide them to position the chassis right where it was when they took it apart, in the same orientation. With younger kids you may want to segregate the 8-32 case screws as they start reassembly... or leave that as a learning experience! Strongly suggest that they start with the system board, while its easy to get at. Guide them in sliding the system board in from the side, making sure it drops into place as it is even with the edge of the black chassis. After they get it into position, and are about to put the two screws in, 'test' it by pulling upward on the corner of the system board that is on the right as viewed from the back. (There are no screws near this, but if the white buttons are in place, it will not lift up. If it does, they were missed, and they need to slide it out again and redo this part.) likewise, 'test' the power supply after they slide it into place. It shouldn't lift up, either, if it has slid properly onto its retainers. The only other important things are that the diskette controller is fairly close to the power supply side, so the ribbon cable will reach OK, that the diskette drive gets screwed in before the speaker gets in the way, and that the power cables to the system board are carefully plugged in in their slightly-off-center position.

Dialog: Building an XT From Scratch

INSTRUCTOR	KIDS / NOTES
OK, think about what *order* things need to go in. Pretty much the reverse of how you took it apart.	(Installing system board, power supply.) Guide plugging in the power connectors to the system board, if necessary.
Do you think it matters exactly which slot you plug the display controller into?	Kids: " No / Maybe / Does it?? "
Notice that the far end of the display card goes into those little plastic slots in the front.	
All the system slots are connected the same. See the printed wires going across all of them?? That's called a BUS, although perhaps Bus-Line would be more appropriate.	Kids: "How about the, uh, disk controller?"
Well, there could be a *mechanical* problem if you put it way over on the end, and the cable couldn't get to the disk drive, right?	
Now, how about the ribbon cable?? Which end goes where??	Kids: "The end with the twist goes to the disk drive!" (Or guide if necessary)
One person can be putting the screws in the power supply while somebody else puts screws into the disk drive.	
Now, a quick test before putting the cover on	Kids: "OK, get the display plugged in, the keyboard. Now the power. OK, switch it on."

would be good! Unless you are really confident. As in *Over*confident!	
(Optional Play-by-play as system comes up)	Kids: "It Works! / Wait, what's a 601 again??"
Guide through using the error codes to debug problems if necessary. Not connecting power to the disk drive is the most common error.	Kids: "It works! It even looks like a regular computer again."
OK, let's put the display on the top, and the keyboard in front, so it looks like one of those computers at school that you're *not* supposed to take apart.	
You guys just built an IBM XT computer in 12 minutes! That's close to the record.[10]	Kids: "Yayyy.."
I have a question for you: If you had a computer, and the disk drive went bad, and somebody gave you a new disk drive, could you replace it??	Kids: "That's easy! It's only two screws and two cables."

Bingo! THAT's what we're trying to do!

[10]Actually the 'record', which we don't want to emphasize, is just under 5 minutes for 6th graders! But that group had this maniac 11 year old girl who had total mechanical recall, and knew exactly where and how everything went together, how many pins each connector had, what keys they had, and what would mechanically interfere during assembly. Neither she or her family had a computer. I told her she could always make a living fixing automatic transmissions.

Bits&Bytes: Where might we go from here??

Computer Demolition is a good one-shot program, and ideally kids will end up with the disposition to want to do more. But that takes some real *content!* ***Bits&Bytes*** is intended to provide that. Although we've done this in various forms, it's not in publishable form, yet! Take a look at **Appendix H** for a quick overview.

CREDITS:

Back in about 1990 or so I was working at IBM and doing this thing where I had kids take XT computers apart and put them back together again, and we were getting lots of other IBM Engineers into doing it too. IBM and I used to call it "Looking Inside The Technology". Lah-dee-dah... My friend **Chuck Griffin** was on leave from IBM to work at the Vermont Institute for Science, Math and Technology. One day he said, "Hey, Terry, when are we going to do another of those **Computer Demolition** things???" Ever since, *That's The Name*!

To Be Continued...

Appendix A. XT Error Code Reference Sheet

IBM PC-XT ERROR CODES

■ **BEEP codes that may occur during POST (Power-On Self Test):**

Beeps	Failure
No display and No beeps	Power
Continuous Beep	Power
Repeating Short beeps	Power or stuck key
1 long and 2 short beeps	Display
1 short beep	Display
2 short beeps	Display

■ **ERROR CODES (Upper Left Screen)**

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101 Main SYSTEM BOARD failure/Processor error.
102 BIOS ROM checksum error. (Try reseating the ROM chips!)
103 BASIC ROM(s) checksum error.

201 MEMORY test failed

301 KEYBOARD did not respond or had a stuck key

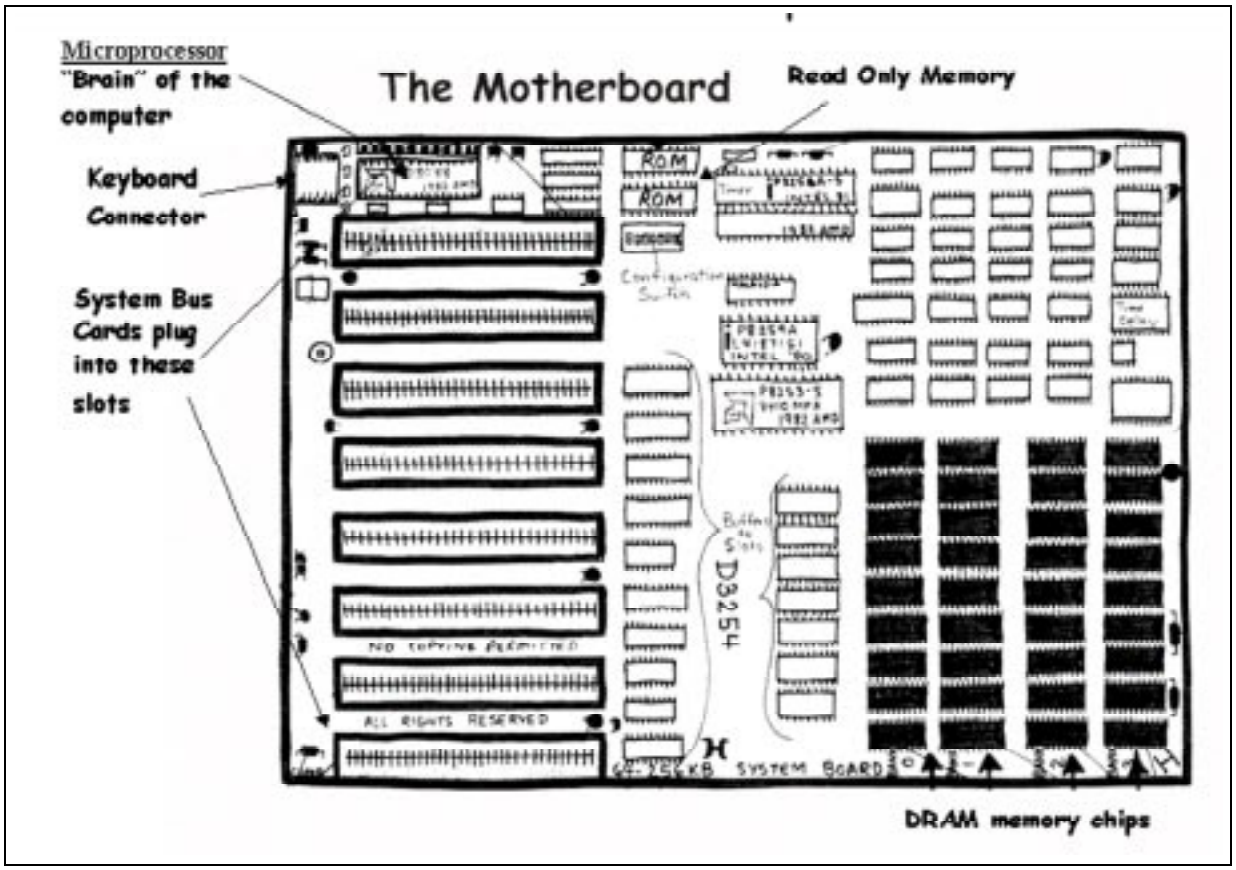
401 MONOCHROME DISPLAY ADAPTER failed
432 PARALLEL PORT test failed (monochrome adapter).

601 DISKETTE power on diagnostics test failed.
602 DISKETTE test failed

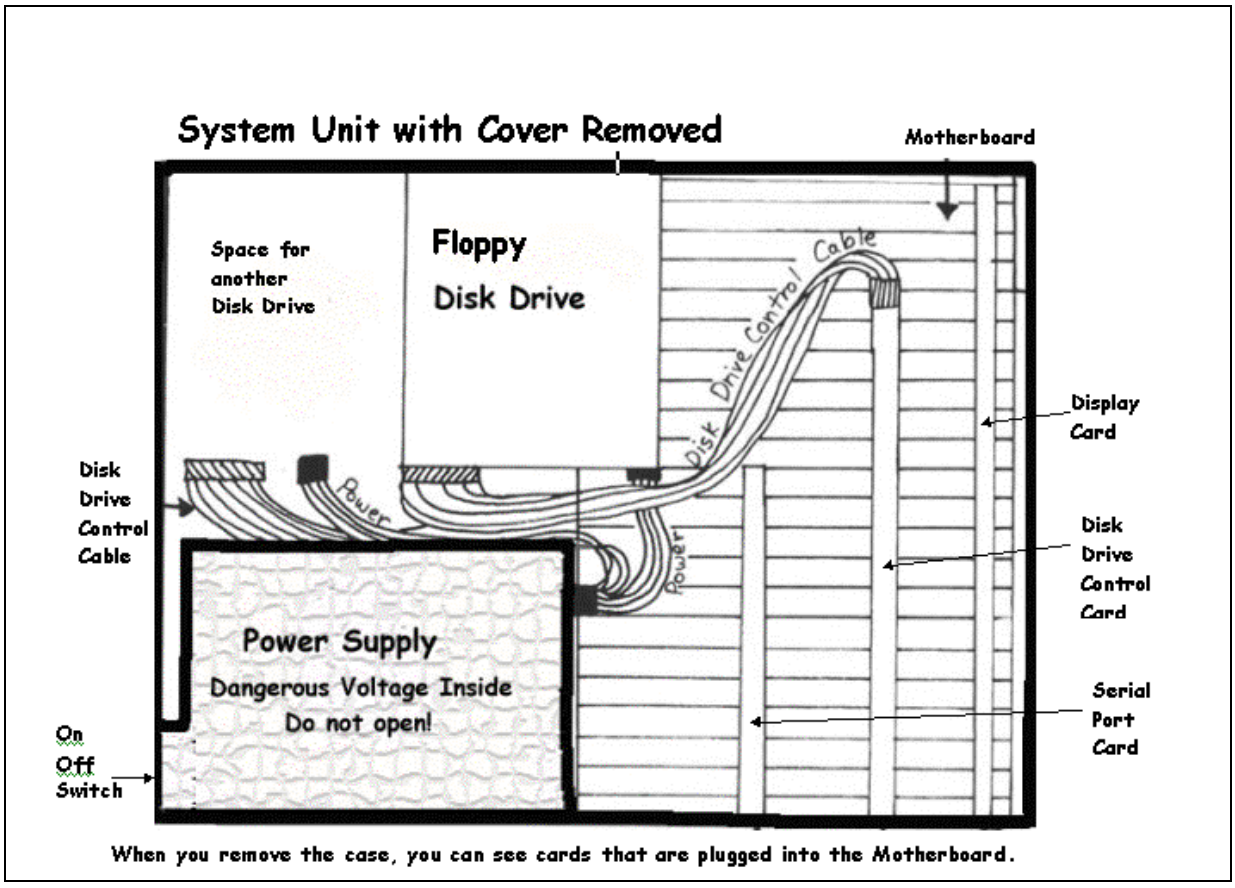
1101 ASYNC (SERIAL PORT) communications adapter test failed.
1301 GAME control adapter test failed

17xx FIXED DISK (HARD DISK) errors:

Appendix B. XT System Board drawing



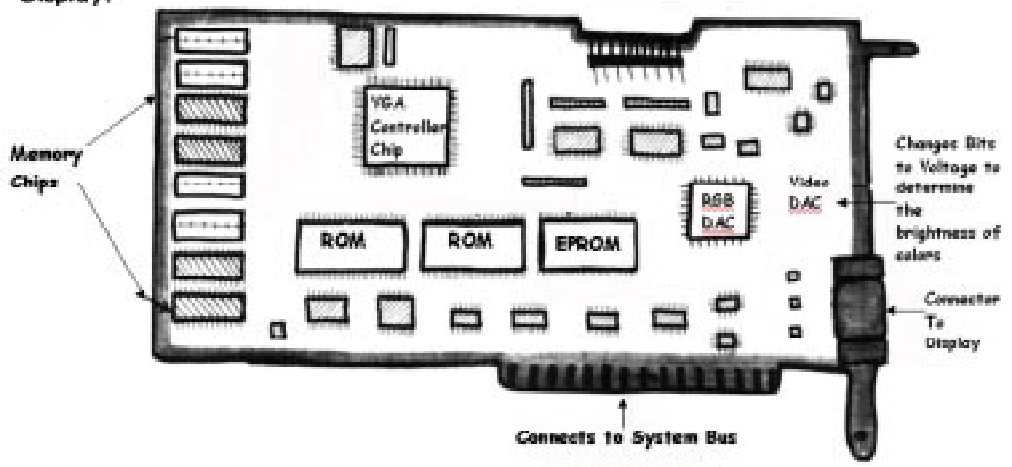
Appendix C. Drawing of System Unit (frame)



Appendix D. Feature Cards:

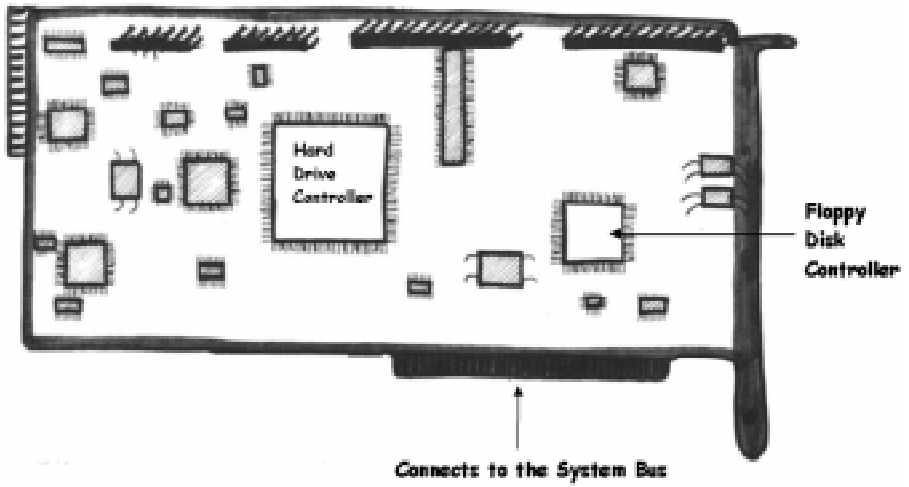
The Display Card

When you take the cards out, you can see that they have many chips on them that do different jobs. This is the Display Card. It controls the Display.



The Disk Drive Control Card

Here is another card called the Disk Drive Control Card. It controls the Disk Drive where you can save files.



Appendix E. Bits&Bytes:

BITS n' BYTES

An Exploration
In Electricity and Computer Science

Bits N' Bytes is designed as a hands-on activity for Elementary through High School students in which they explore and learn about "Those Bits that everyone knows are inside computers".

Although Bits N' Bytes is intended to be a classroom unit that takes place over 8 to 12 sessions, the material has also been used to develop an introductory one session presentation suitable for use in National Engineers Week and other outreach activities.

Everybody knows that computers run on BITS... and there's LOTS of them in there! BUT:

- What are bits LIKE?
- What do they DO?
- How do bits get IN to the computer, and where do they come OUT?
    - How can we get bits to come OUT of the computer where we can see them and play with them?
    - How many kinds of bits ARE there?
    - What do bits MEAN?

- What does it mean when you have more than one bit at a time?
    - What can we tell bits to DO??
    - What does the computer DO with bits, anyway?
    - If we have TWO bits, what does AND mean? OR? NOT?
    - What things do we see and use every day that are LIKE bits?
    - How are switches and lights like bits? Your house Thermostat?
    - What are LEDs? (Light Emitting Diodes). What makes them light up?
    - Where do we hook up wires to the computer to get bits to come out and light up LEDs?
    - Where do we hook up wires to the computer so our switches will become bits?
    - What are the SYMBOLS for Switches, and Lights? Draw a DIAGRAM of what you are hooking up.
    - How can we hook up switches to make AND? How about OR?
    - What are the SYMBOLS for AND and OR "GATES"?
    - What's a MATHEMATICAL operation? What's a LOGICAL operation?
      What do they look like if we write them down on paper?
    - What are the SYMBOLS for AND, OR and NOT in a logical operation?

- If we make GROUPS of bits, how big should a usual group be?
      What would the NAME of that kind of group be?
    - Can we use all the bits in a group as individuals?
    - The bits we are using were made to usually go to the printer and print characters and words and lines and pages. How can a group of bits tell the printer what character to print?
    - What bits have to be ON and OFF to make the letter "A"? How about "a"?
    - What is the BYTE that tells the printer to go to a new line?
    - Write down the BYTES that make up your name. Put them into the computer.
      Make the computer send them to the printer.11
    - What would the bytes for a whole page look like?

- How do we use bits differently to make NUMBER VALUES instead of CHARACTERS?
    - What is the BYTE that equals ZERO? ONE? TWO? FOUR? THREE?
    - What SET does each column (BIT) in a BYTE stand for?
    - What is the LARGEST number you can have with 8 bits?
    - Make the byte for 8. Then one for 11. Show how to ADD them

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[11] Otherwise bits 'n bytes can also be sent to the screen.

- Now, use bits as individuals for OUTPUTS. Hook up more than one light. Hook up some OTHER things that can be ON or OFF, like beepers, or magnets with flags, or butterfly wings, or motors.
    - The bits coming out of the computer are not strong enough to run more powerful actuators like motors, electromagnets and MuscleWires. Hook up a TRANSISTOR to a bit that you need to be more powerful.

- Hook up some OTHER things that can be INPUTS. Like special switches that are SENSORS.
- What PHYSICAL QUANTITIES in your classroom can you think of to sense?
  How about TEMPERATURE? LIGHT? AIR FLOW? PRESSURE? WEIGHT?
  With one bit can you tell HOW MUCH? Or just MORE OR LESS?
- Explore how to write PROGRAM statements that tell the computer what INPUT BITS to look at, how to DECIDE what to do, and what OUTPUT bits to turn on. Make the computer turn ON "your" light when "your" switch is ON.

- Tell the computer to blink your light on and off quickly. How do you tell it HOW LONG AT A TIME to turn it on? How do you tell time for short times less than one second? What do you call 1/1000 of a second? A MILLIONTH of a second?
- Explore how to tell the computer to do one thing after another after another in SEQUENCE.
- DESIGN some strange device or machine. Make it out of cardboard etc.. Put switches, lights, sensors or actuators on it. Wire them up as INPUTS and OUTPUTS. Write a computer program that looks at the INPUTS, makes DECISIONS, decides the SEQUENCE of things, and turns the OUTPUTS on and off. Try it out. It probably won't work right the first time, so DEBUG it.

Materials and Prerequisites:

- An IBM type Personal Computer, with a regular parallel printer port card
    - Some wire, LED's (Light Emitting Diodes), switches, sensors, beepers etc.. (Less than $25 at Radio Shack)

- (Optional) A Printer and a Cable Breakout Board (makes it easy to get at the bits).

- (Optional) More and Better SENSORS and ACTUATORS, such as Motors, Thermostats, Electromagnets, MuscleWires (tm) etc..

- BITNBYTE “PARPORT” software (Freeware)
- The BITS 'N BYTES Guidebook (Under Construction!)

Learners should have previously done the activity called "PC Demolition" in which they completely disassemble and reassemble an XT type computer. This can done concurrently.

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