PROJECT PROPOSAL AND FEASIBILITY STUDY

STREAM COME TRUE
TEAM 10

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SENIOR DESIGN
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Abstract

The purpose of the project is to design a streaming media system aimed at augmenting the existing Hekman Library Cayvan media area using modern digital archiving, storage, retrieval, and playback methods in conjunction with the newly implemented CIT wireless infrastructure. The system will have a handheld device, a central media server, and a video terminal. The team has decided to use a single board computer for the handheld device. The project is feasible and will be completed by May 2006. The first semester has been allocated for logistics, budget, and parts acquisition, while the second semester has been allocated for designing and testing of the system. This document serves to explain the project, its design and also focus on the feasibility of the project.

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1. Introduction

The project is intended for use in multimedia areas of public institutions, such as university libraries. The multimedia area in Calvin's Hekman Library is called the Cayvan media area. Currently the Cayvan collection is comprised of a large assortment of physical audio and video media that can be used by students at listening stations in pre-designated sections of the library. Figure 1 shows the current implementation of the Cayvan video viewing room (left) and the listening station (right). There are two primary drawbacks to this system. The first is the amount of effort that has to go into organizing and maintaining such a sizeable collection of physical media. The Cayvan collection is comprised of over 40,000 dollars worth of physical media, with over 2,000 choral pieces from Calvin's choir alone.[1] The second primary drawback is the somewhat limited nature in which the various media types can be accessed. There are limited copies of all the media, so only a small number of students can view the media at any given time. Also, the media is physical, so it requires actual storage space. While the current system is adequate, using current generation digital media archival techniques could enhance this solution.

Figure 1 - Cayvan Video Viewing Room and Listening Station

Our project will use handheld computer systems to stream audio and control video streams from a centralized media storage network. The number of handheld computer is dependant on the desires of the institution purchasing the system. Our project will be to create one prototype, but a production system can have as many as is desired. The number of handheld devices purchased will affect the price of the system. Refer to the budget, located in the appendix, for more details. Cayvan library media will be accessible via streaming audio over the library's wireless network. The audio, most likely streaming mp3 format, will stream and playback through a handheld audio computer. Any media available on the library's media server will be accessible via the user interface on the handheld device. This server will be able to contain audio such as Calvin's chorale selections, audio books, as well as any other audio media currently available. In terms of video, the handheld device will control a video stream that is displayed on a separate video terminal. The video will most likely be AVI format, and will include DVD's, VHS tapes, and any other video media that is currently available.

The interface on the handheld computer will be context specific. The video aspect of the system will be implemented via thin client systems wired to the library LAN. These thin client systems will have no external human interface devices. Instead they will be controlled by the handheld computer systems via Bluetooth, which is a wireless communication standard. When a handheld computer detects a Bluetooth signal it will display a video selection interface. The user will then be able to select any available video media. The selected video will then stream to the user-specified thin client terminal.

Our team, Stream Come True, is currently enrolled in Engineering 339/340, which is a Senior Design class at Calvin College. Senior Design is the capstone course of the engineering program. This

[1] Cayvan Services. 17 Aug. 05. The Hekman Digital Library. 3 Dec. 05.
< http://www.calvin.edu/library/cayvan/tutor/main.stm>

course provides the team with the opportunity to go through the design process and applicable design norms. The design process includes defining a problem, and providing a solution through a new idea or revised design that focuses on the design norms as its foundation. The design team also provides a feasibility analysis and report which is the primary scope of this document.

Team Stream Come True is comprised of 4 electrical engineers, shown in Figure 2 below, and 1 computer science student. The four electrical engineers are Ben Bufford, Jermey Gajadhar, Nick Goote, and Andrew Oosterhouse. Ben Bufford is originally from Colorado Springs, CO. His interests include embedded systems and open source operating systems. Jermey Gajadhar currently resides in Grand Rapids, MI. His interests are computer technologies and musical instruments. Nick Goote is originally from Grand Rapids, MI. After graduation, his plans involve either attending graduate school or entering the workforce. Andrew Oosterhouse is also originally from Grand Rapids, MI. He hopes to attend graduate school after receiving his degree from Calvin. Jason Roelofs, the computer science student, is a senior at Calvin College, and currently resides in Grand Rapids.

Figure 2 – Team 10 – From Left to Right – Jermey, Andrew, Nick, Ben

The remainder of the report includes the Educational and Design Objectives that our team hopes to address, as well as the Design Norms that our team hopes to keep in mind during the project. It will continue with a list of the tasks that our team hopes to accomplish, the research we have done, the project management overview, and team organization. The report will then launch into a preliminary feasibility analysis, description of software design, project requirements, and a description of the system design.

2. Terms

IMS	Integrated Media System
ARM	Advanced RISC Machines
SCT	Stream Come True (Team 10)
BGA	Ball Grid Array
OS	Operating System
PCB	Printed Circuit Board
LAN	Local Area Network
IEEE	Institute of Electrical and Electronic Engineers
PCMCIA	Personal Computer Memory Card International Association
SBC	Single Board Computer
RF	Radio Frequency
WRL	Western Research Laboratory
URI	Uniform Resource Identifier
VLC	Video LAN client
GUI	Graphical User Interface
SDP	Service Discovery Protocol
MAC	Media Access Control

3. Educational and Design Objectives

3.1 Objectives

3.1.1 Design Functionality

Stream Come True (SCT) seeks to design an integrated media solution for use in the Hekman library. The system will allow for centralized digital storage of both video and audio media. From this centralized server, the end-user will be able to access both audio and video media.

In the case of video media, the video will be streamed to a video terminal over the library's wired LAN, while the soundtrack which accompanies the video will be streamed to a handheld device over an 802.11b network. The video terminal will be based on a thin-client computer. This system implementation is shown in figure 3.

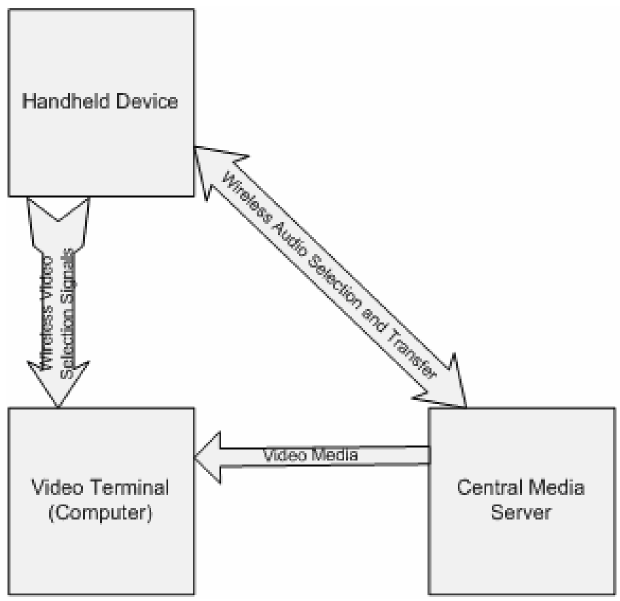

Figure 3 - Full System Implementation

In the case of audio media, only the handheld device will be utilized. This implementation is shown in Figure 4. The handheld device will be equipped with Bluetooth which will be used to communicate with the video terminal which is receiving the video stream. This Bluetooth connection will allow the handheld to make sure the audio stream and video stream are in sync, as well as alert the video terminal as to which video it should request from the central server. The Bluetooth also allows the handheld to be used with any video terminal. This independence from any single video terminal will allow the handheld to be used with all properly connected video terminals in the library.

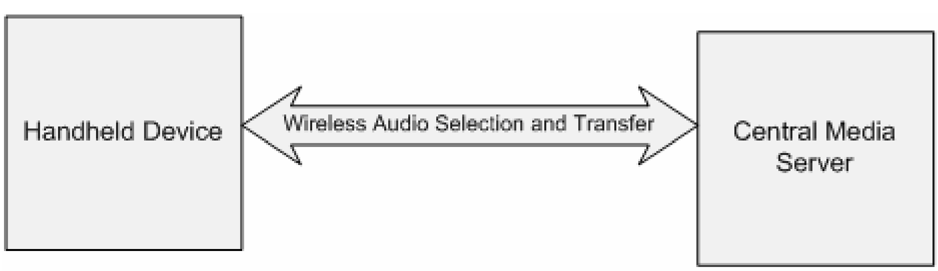

Figure 4 - Audio Only Implementation

3.1.2 Educational Opportunities

This project presents SCT with significant educational opportunities. Through this project the members of SCT will be exposed to PCB Design and Layout, Integration of Software and Hardware, Time Management and Scheduling, Team Work and Budgeting Skills.

3.1.2.1 *PCB Design and Layout*

SCT will require the use of PCB layout and design software. Since the handheld device has its own schematic, the team is only responsible for designing the daughter card.

3.1.2.1.1 ***Board Requirements***

The Daughter card design requires at least a 2 layer board. For the handheld device, a 4 layer PCB daughter card is required.

3.1.2.1.2 Tool Requirements

The current capabilities for PCB design at Calvin are limited. The team is looking into using a full edition of Eagle which has all the features necessary. There will also be a steep learning curve involved in learning the software since SCT has only used single layer PCB software.

3.1.2.2 *Integration of Software and Hardware*

The scope of this project requires the team to have good working communications with the Computer Science student that is part of our group. The computer science student will be producing all the software necessary for the handheld device to communicate to the media server. SCT would also be building device drivers for the Daughter card, which allow the Daughter card to use Bluetooth and 802.11 communication.

3.1.2.3 *Time Management and Scheduling*

The success of any project starts with good scheduling and time management. Time management involves each individual of the team planning their personal time and team interaction time in an effective and efficient way. Scheduling involves the planning of assignments and tasks so that all of the project goals will be completed on time. SCT decided to use Microsoft Project to schedule all of its tasks. Given Microsoft Project's widespread use in industry, this gives our team a good opportunity to learn tools that we will need to use in the future. The team also made a Task Specifications list for a more detailed idea of how long a certain task should take.

3.1.2.4 *Team Work*

3.1.2.4.1 Individual Skill Sets

Almost all projects in the industry are completed by team work. Each person has a valuable and necessary contribution. Ben has a lot of background knowledge on Linux and open source software. He is also good at contacting people about getting part information and pricing. Jermey is adept at PCB design and researching the functionality of different parts. Andrew has experience at hardware design and implementation, as well as hardware debugging and documentation. Nick has some experience in hardware design, debugging, and documentation, and also in software design. These individual skill sets give us a well rounded team and a wide variety of skills to draw on. SCT realizes the importance of team work and understand how the dynamics of teamwork plays into the success of our project.

3.1.2.4.2 Conflict Resolution and Team Delegation

The team shall delegate tasks in way that parallel work will happen with little or no hiccups. Understanding the concepts of team dynamics and teamwork is an important skill needed for real world applications. When someone does not complete their task by the given deadline, we have a team meeting and discuss what changes need to be made to get back on track, as well as what changes need to be made to the individuals work ethic. If a technical disagreement arises, the team does more research to get to the bottom of the matter. If a design decision is required, then the entire team is involved in that decision.

3.1.2.5 *Budgeting Skills*

Our team takes the budget very seriously because it affects the feasibility of our project. In light of that, SCT is also proposing a budget to a local company Smiths Aerospace. Smiths Aerospace has expressed interest in the project of SCT therefore a professional budget is necessary. SCT has also taken the additional step of breaking its budget down into a prototype and production for future analysis. Understanding the skills of budgeting is a well worthy educational opportunity for all individual. Chances are high that each individual will be ordering parts or be involved in budgeting.

3.2 Conditions for Success

The project shall be considered a complete success if a wireless device is constructed by the end of May 2006 which allows for the reception of streaming audio, as well as the control of a video that is being displayed on a video terminal. There are varying degrees of success that the team is willing to accept, depending on the hardships and design difficulties that are encountered. As of right now, we are planning on implementing both Bluetooth and 802.11, but we would still consider the project a success if only one of these protocols was in place. We would also consider the project a success if we only got the audio aspect of the project working, and not the video.

4. Design Norms

Design Norms are general principles that relate to how to design correctly. These norms are moral rather than physical or legal guidelines. By following these norms, the engineer is forces to take a step back and take a look at how the design affects the environment in which it will be used. SCT desires to take a look at how our design will affect the environment in which it is used, and will utilize design norms for this purpose.

According to Gayle Ermer, Associate Professor of Engineering at Calvin College, "Technology is a tool that needs to be shaped by Christian values to be effective in ministering to the needs of the world."[2] These ideas are epitomized by the design norms of cultural appropriateness, transparency, stewardship, and caring.

The first design norm is cultural appropriateness. This design norm focuses on how well new technology fits into the society that will make use of it. The Itsy is made with this design norm in mind. Given that our project will be designed for the Calvin College Hekman Library, it is critical that we design the Integrated Media System (IMS) to fit into the culture of Calvin, and more generally, the culture of the USA. It is also important to consider how our project might be applied after we finish our proof of concept. In light of that, the design needs to be easy to use and easily adaptable to not only Hekman Library, but any other location that might use it. An excellent way in which this consideration can be implemented is to give the Itsy and its support equipment multi-language support, which will allow it to work on an international scale.

Next, it is important to consider the design norm of transparency when designing the IMS. Transparency is designing the system to be as open and understandable as possible to the end user and everyone involved in the design. This does not necessarily mean disclosing every design detail to the end user. For example, software companies rarely disclose source code because it may be proprietary. However, they do disclose information on exactly what the code is meant to do, and how reliable the code

[2] Ermer, Gayle E. "Reflections on Integration Engineering into my Christian Life," *Faith and Learning Article, 2002*. Grand Rapids, MI: Calvin College, 2002.

is. Our team is striving to fulfill this design norm by using Open Source software for the Itsy handheld device, as well as using freely available hardware specs to build the Itsy itself. Using Open Source allows for more detailed documentation of all hardware components, as well as all software programs. This allows our team to provide very thorough documentation about how the IMS will function to all end-users of the system.

Stewardship is also an important consideration for our design. Stewardship is the idea of designing a system that doesn't use more resources than required to meet the goal. This can take many forms. These can include monetary stewardship, stewardship of natural resources, or stewardship of assets such as time, labor, buildings, etc. By utilizing our design, Hekman Library stands to save both space and money, allowing for better stewardship of both physical and economic resources. Space will be saved by converting the large amount of physical media to digital files which can be archived on central media servers. The IMS will also allow for possible elimination of the separate viewing rooms since the system is completely portable and has headphones. Economic resources will be saved by reduced storage costs, as well as the expandability of the IMS. If, in the future, Hekman Library wishes to increase its Cayvan media capabilities, it could easily do so by simply obtaining more IMS equipment. The only limit to the scalability of the system would be the overall bandwidth of the available wireless network, the number of video terminals, and the size of the building. With the old system, expanding Cayvan could possibly require an addition to the library building, or at the very least additional storage space. The Itsy serves as a single easy and economic solution to the expansion of the Cayvan media libraries. It is important to our team that we use resources efficiently. The cost that is saved in producing videos, DVDs, and also building materials could be funded to other areas.

Caring is the idea of designing a system that will have a positive effect on people. The main way in which the team applies this norm is by caring for people with physical disabilities. Our project will enable greater access to Cayvan's media library for all library patrons. This includes persons who may be physically handicapped and unable to use the current facilities. Under the current system, those in wheelchairs must make their way to the Cayvan desk, dodging students and library furniture in the process. After reaching the desk, they must get themselves into a small viewing room where wheelchair mobility is restricted. The rooms are small, and given the amount of furniture in the room, making adjustments to the AV setup can be a hassle. For example, if a wheelchair bound person wanted to play a VHS tape, they first must obtain the tape from the desk, take the tape to the room, put the tape into the VCR to begin viewing. This is clearly feasible, but more difficult for someone in a wheelchair in a library crowded with students and furniture. If Cayvan was using the IMS, the media becomes much more accessible, allowing Cayvan to serve more people. Depending on the extent of the wireless media, Calvin could also bring their library archives to the student's room through steaming media if needed, thus making Calvin a friendly environment for people with disabilities.

5. Project Task List and Time Allocation

Table 1 - Task Specifications

Task			Estimated Time Needed	Actual Time Needed
Project Management				
	Status Reports			
		Time Keeping	8 hours	3 hours
		Writing Report	8 hours	3 hours
	Schedule Management			
		Making Schedule	8 hours	6 hours
		Updating Schedule	8 hours	4 hours
	Budget Reporting		8 hours	3 hours

	Team Meetings				
		Meeting with Industrial Consultant		4 hours	2 hours
		Formal Team Meetings		8 hours	4 hours
		Informal Team Meetings		20 hours	8 hours
Overall System Design					
	Overall project goals			8 hours	5 hours
	Viable project alternatives				
		Initial ITSY Feasibility		4 hours	4 hours
		Initial Single Board Computer Feasibility		4 hours	4 hours
		Initial PDA Feasibility		4 hours	1.5 hours
ITSY Device					
	Feasibility				
		Determine overall cost of fabrication		8 hours	3 hours
		Determine overall cost of assembly		3 hours	2 hours
		Determine overall cost of Digikey parts		8 hours	8 hours
		Determine overall cost of obsolete parts		8 hours	16 hours
		Determine interface possibilities		3 hours	8 hours
		Determine overall Time for assembly		3 hours	1 hour
		Determine tools required		8 hours	3 hours
	Assembly				
		Procure Digikey parts		4 hours	0 hours
		Procure obsolete parts		8 hours	0 hours
		Have PCB fabricated		1-3 weeks	0 hours
		Pre assembly testing			
			Make IC Breakout boards	8 hours	0 hours
			Make analog Breakout boards	8 hours	0 hours
			Board Continuity Test	8 hours	0 hours
		Solder IC's onto board (Final Assembly)		8 hours	0 hours
		Solder analog components onto board (Final Assembly)		8 hours	0 hours
	Software (EE tasks)				
		Compile and install Operating System		8 hours	0 hours
		Find necessary device drivers			
			Examine Linux Kernel for native device support	8 hours	0 hours
			Search for pre-made open source drivers	8 hours	0 hours
			Research implementation of pre-made drivers	8 hours	0 hours
		Design necessary device drivers			
			Research programming of device drivers	8 hours	0 hours
			Search for device driver examples	8 hours	0 hours
			Search for similar device drivers	8 hours	0 hours
			Program Device Driver	50 hours	0 hours
		Debug any OS or driver related problems			
			Debug OS related problems	8 hours	0 hours
			Debug driver installation problems	8 hours	0 hours
			Debug driver compile problems	8 hours	0 hours
			Debug driver functionality problems	8 hours	0 hours

	Testing and Debugging				
		Identify requirements to be tested		8 hours	0 hours
		Identify additional tests		5 hours	0 hours
		Write test checklist		2 hours	0 hours
		Identify/Procure test equipment needed		8 hour	0 hours
		Run driver tests		8 hours	0 hours
		Run handheld tests		8 hours	0 hours
		Document test results		8 hours	0 hours
		Re-run tests		8 hours	0 hours
Single Board Computer Device					
	Feasibility				
		Determine interface possibilities		8 hours	
		Determine tools required		8 hours	
	Assembly				
		Procure Digikey parts		8 hours	1 hours
		Procure obsolete parts		8 hours	0 hours
		Assemble Parts		8 hours	
	Software (EE tasks)				
		Compile and install Operating System		8 hours	0 hours
		Find necessary device drivers			
			Examine Linux Kernel for native device support	8 hours	0 hours
			Search for pre-made open source drivers	8 hours	0 hours
			Research implementation of pre-made drivers	8 hours	0 hours
		Design necessary device drivers			
			Research programming of device drivers	8 hours	0 hours
			Search for device driver examples	8 hours	0 hours
			Search for similar device drivers	8 hours	0 hours
			Program Device Driver	50 hours	0 hours
		Debug any OS or driver related problems			
			Debug OS related problems	8 hours	0 hours
			Debug driver installation problems	8 hours	0 hours
			Debug driver compile problems	8 hours	0 hours
			Debug driver functionality problems	8 hours	0 hours
	Testing and Debugging				
		Identify requirements to be tested		8 hours	0 hours
		Identify additional tests		5 hours	0 hours
		Write test checklist		2 hours	0 hours
		Identify/Procure test equipment needed		8 hour	0 hours
		Run driver tests		8 hours	0 hours
		Run handheld tests		8 hours	0 hours
		Document test results		8 hours	0 hours
		Debug problems discovered during test		8 hours	0 hours
		Re-run tests		8 hours	0 hours
Daughter-card					
	Research necessary components				

		Research Bluetooth			
			Research IC’s	8 hours	5 hours
			Research Development Kits	8 hours	5 hours
			Research Bluetooth Software	8 hours	0 hours
			Analyze Options	8 hours	0 hours
			Select Solution	8 hours	0 hours
		Research 802.11 hardware and software			
			Research IC’s	8 hours	5 hours
			Research Development Kits	8 hours	5 hours
			Research Software	8 hours	0 hours
			Analyze Options	8 hours	0 hours
			Select Solution	8 hours	0 hours
		Research power requirements and implementation of daughter-card			
			Research Power Requirements	8 hours	0 hours
			Research Possible Interfaces	8 hours	4 hours
			Choose Best Interface	8 hours	0 hours
	Research board fabrication				
		Research trace length/width requirements		4 hours	1 hours
		Research number of required board layers		8 hours	3 hours
		Research local board fabricators		8 hours	4 hours
	Schematic Design				
		CAD software			
			Analyze different CAD options	8 hours	4 hours
			Test different options	8 hours	4 hours
			Choose best option	8 hours	4 hours
			Software Tutorials	8 hours	2 hours
			Practice PCB design	8 hours	0 hours
			Practice Schematic design	8 hours	1 hours
			Design Daughter card	8 hours	0 hours
			Layout daughter card on PCB	8 hours	0 hours
		Identify relevant requirements		8 hours	0 hours
		Obtain Simulation Software		8 hours	0 hours
		Run necessary simulations		8 hours	0 hours
		Have schematic reviewed by Corrin		8 hours	0 hours
	Send board out for fabrication			2 hours	0 hours
	Test and debug daughter card				
		Identify requirements to be tested		8 hours	0 hours
		Identify additional tests		4 hours	0 hours
		Write test checklist		4 hours	0 hours
		Identify/Procure test equipment needed		8 hour	0 hours
		Run tests			
			Run IC tests	8 hours	0 hours
			Perform Continuity tests	8 hours	0 hours
		Document test results		6 hour	

		Debug problems		30 hours	
			Identify problems	7 hours	0 hours
			Design tests to isolate problems	7 hours	0 hours
			Test isolated problems	8 hours	0 hours
			Repair problems	8 hours	0 hours
			Document repair	4 hours	0 hours
			Update Schematic	6 hours	0 hours
			Document test results	4 hours	0 hours
		Re-run tests		4 hours	
	Design daughter-card to Itsy Interface			50 hours	
		Identify interface options		8 hours	0 hours
		Analyze advantages of each option		8 hours	0 hours
		Choose best option		8 hours	0 hours
		Design interface based on best option		8 hours	0 hours
		Test interface		8 hours	0 hours
		Implement interface		7 hours	0 hours
	Test and debug combined system				
		Define tests		8 hours	0 hours
		Run tests		8 hours	0 hours
		Document results		8 hours	0 hours
		Isolate problems		7 hours	0 hours
		Test isolated problems		7 hours	0 hours
		Repair problems		8 hours	0 hours
		Document results		6 hours	0 hours
		Re run tests		4 hours	0 hours
		Update Schematic		5 hours	0 hours
Media cataloguing system					
	EE tasks				
		Catalog audio and video		5 hours	
		Procure Thin Client Terminals		5 hours	
		Procure Server Computer		5 hours	
		Obtain Bluetooth cards			
			Select Vendor	5 hours	
			Decide on card	8 hours	
			Procure Card	3 hours	
Budget					
	Obtain external funding.				
		Submit proposal/budget to Smiths		8 hours	6 hours
		Contact PCB Express for donations		3 hours	1.5 hours
		Procure funding from Smiths		8 hours	0 hours
	Produce detailed budget for both handheld and daughter-card				
		Produce detailed budget for ITSY		8 hours	7 hours
		Produce detailed budget for SBC		8 hours	3 hours
		Produce detailed budget for daughter-card		8 hours	4 hours
		Produce production budget		8 hours	3 hours

		Periodically revise budgets	5 hours	2 hours
CS tasks				
	Media Cataloguing System			
		Design custom interface software for thin client/server interface	60 hours	
		Debug and test custom software	40 hours	
		Implement custom software	10 hours	
	Handheld Software			
		Design and compile custom software		
		SBC media selection software	30 hours	
		Thin Client Software	10 hours	
		Upload custom software to memory	1 hour	
		Debug custom software problems	20 hours	
Prepare PPFS				
	Write detailed table of contents		5 hours	5 hours
	Write PPFS		40 hours	5 hours
		Write Introduction/Conclusion	3 hours	2 hours
		Write Educational and Design Objectives	6 hours	4 hours
		Write Design Norms	4 hours	3 hours
		Write Project task list and time allocation	8 hours	6 hours
		Write Research section	8 hours	6 hours
		Write Project Management	5 hours	4 hours
		Write Team Organization	5 hours	4 hours
		Write Preliminary Feasibility Analysis	8 hours	7 hours
		Write Software Design	5 hours	3 hours
		Write Project Requirements	8 hours	7 hours
		Write System Design	8 hours	6 hours
Prepare final presentation for project night				
	Write presentation			
		Write Project Night Presentation	8 hours	0 hours
		Write Final Class Presentation	7 hours	0 hours
	Rehearse presentation		20 hours	0 hours
Prepare final report				
	Write final report			
		Write Chapter 1	8 hours	0 hours
		Write Chapter 2	8 hours	0 hours
		Write Chapter 3	8 hours	0 hours
		Write Chapter 4	8 hours	0 hours
		Write Chapter 5	8 hours	0 hours
		Write Chapter 6	8 hours	0 hours
		Write Chapter 7	8 hours	0 hours
		Write Chapter 8	8 hours	0 hours
		Write Chapter 9	8 hours	0 hours
		Write Chapter 10	8 hours	0 hours
		Write Chapter 11	8 hours	0 hours
		Write Chapter 12	8 hours	0 hours

	Proofread final report	15 hours	0 hours
Pray		∞	∞^42
Total Hours			

6. Research

Research has been conducted to determine effective means and resources to implement the initial project concept. The primary feasibility efforts have centered on the single board computer and the accompanying wireless components (Bluetooth and 802.11). Research was devoted to part identification, part selection, and vendor location for both. The aspects of the overall system beyond the SBC and custom daughter-card are addressed in the system design section of this document since the specification of fully designed and assembled sub systems was the main requirement (e.g. Thin client and server systems).

Finding parts has remained one of the biggest feasibility challenges to this project. The scope of this endeavor is necessarily broad as it entails determining not only what the parts specified on the Itsy bill of materials actually are but also the selection of parts for plausible SBC alternatives. For the alternative parts specification the burden of identifying and procuring every individual board level part is eliminated, but integration issues already addressed within the breadth of the Itsy spec are raised. The areas of concern – with respect to integration – involve specifying parts beyond the SBC board level such as LCD, battery, human interface devices, and unit housing. Each option poses a somewhat unique set of logistical and design challenges.

Part selection and vendor location are closely related given that the affordability and availability of a part heavily influence whether it is selected. Again, the issues for the Itsy and alternative SBCs are somewhat different. Since the Itsy is delivers a complete specification the simplest course of action is to simply find the requisite parts with less attention given to the price or available vendors. Whereas, the selection of a pre assembled SBC would be heavily determined by cost and availability. The part selection process for the daughter card components is the same regardless of the SBC platform. While determined by essentially the same as the selection criteria as the SBC, board complexity required by a given part and the avoidance of ball grid array components are additional areas of concern for the daughter card.

6.1 Literature Search

The portable computing aspect of the project is defined as being the handheld device – Itsy or SBC – once fully assembled and ready to interface with a daughter-card. While the daughter-card is defined as any additional hardware added to a fully assembled SBC. SBC is used to reference a device for this project.

The Itsy is well documented and much of the literature for that alternative is provided directly through Hewlett Packard and Compaq labs. Some of the general project portable computing concepts were derived from the specifications and capabilities described in the WRL Technical Note "TN-54"[3]; notably the basic physical dimensions, ARM CPU architecture, and daughter card concept. This documentation provides a good overview of SBC (single board computer) baseline functionality. As with any computer design project data sheets for various components have also been an integral part of research for the project.

[3] Virdaz, Mark. "The Itsy Pocket Computer Version 1.5 User¹s Manual." University Avenue Palo Alto, California 94301 USA. (1998) 1 Sept 2005.

6.1.1 Single Board Computer

With funding still pending the WRL Itsy is an unlikely candidate for the SBC computer to be used for the project. Initially it was favored because in depth information on this platform is openly published. Since it provides visibility to every aspect of the SBC design it makes an excellent platform for education, research, and expansion.

Despite the inherent educational advantages of the Itsy, early part procurement efforts have been largely unfruitful, severely inhibiting the feasibility of this particular solution. The Itsy design requires over 185 components; 17 of the most critical being obsolete. These components must be acquired through specialty parts vendors. Dealing with obsolete parts vendors has been the largest source of procurement difficulty. These parts have shown unacceptable lead times for our scheduling constraints and are priced at a substantial premium due to their limited availability. Most of the parts vendors also impose minimum purchase requirements that far exceed the project needs or budget, and they have show little willingness to even consider doing business with students even on the terms of their (vendors) purchasing requirements. Given these difficulties concurrent research has been conducted on alternative compact SBC options. Intel's ARM architecture is favored based on its prevalence in similar embedded platforms, compact form factor, integrated power management featureset, and highly integrated I/O. The I/O design of the Intel Xscale ARM architecture allowed for simplicity in designing the daughter card expansion and the PXA270 variant favored for prototyping also eliminates the need for external audio hardware. X86 alternatives have been considered due to the sheer volume of software available for that architecture, but the majority of alternative SBC research has been devoted to ARM based designs.

The primary criteria for consideration are centered on size, software availability (for the architecture is in question), software flexibility provided by the performance of the hardware resources, the expandability of the SBC based on industry standard bus, data transfer, and interconnect standards.

Size is important for a mass produced product but not as important for rapid prototyping. The size criterion for the prototype design stipulates that the portable computing device be self contained and practical to move and carry while using with the daughter card attached. There should be no inhibiting factors such as external, attached wiring or weight in excess of five pounds. Regardless of the prototype dimensions the selected components for the portable computer and daughter card must be proven to scale down to dimensions of 152mm x 102mm x 80mm or less when adequate fabrication resources are available. In order for fabrication resources to be considered adequate they must assemble a complete portable device and daughter card within the maximum dimensions without exceeding the fabrication costs outlined in the production budget.

Software availability is critical to the success of this project. At the system level it depends heavily on effective utilization of software to provide the needed interfaces between users and devices as well as control for the various interfaces between sub-systems within the aggregate system. The areas of greatest importance are an operating system that allows a straightforward means for developing new device drivers; ready made multimedia codecs for audio and video; and an easily programmable graphical environment for the user interface. Open source software was chosen for every aspect of the project and any SBC considered must be able to run GNU/Linux along with all of the GNU/Linux software libraries required by the project

The SBC hardware must be fast enough to decode streaming Vorbis audio in real time while sustaining a responsive user interface. It must also have the memory resources to have all system, user, and multimedia software active simultaneously and the storage resources to hold all of this software on board. Any SBC considered must meet these hardware criteria. The SBC must also offer at least one type of industry standard expansion bus. The standards of primary interest are USB and PCMCIA. These hardware requirements are mandatory.

Some basic performance comparisons were done based on ARM Vorbis decoding research. This analysis indicated that a 200MHz ARM CPU experiences approximately sixteen percent utilization when decoding a 192kbps stream. The remaining Eighty-Four percent is adequate for OS overhead and the network and Bluetooth devices. 200MHz or better delivers suitable hardware performance for the project.

The portable devices described here met the criteria stated above and were considered for use on this project.

The ITSY offered an excellent option and was the initial choice for the portable device. It has complete X11 and Linux environments prepared by Compaq as well as the hardware resources to meet the bus and performance requirements. Part availability was the primary reason this option was not selected.

A number of alternative SBCs were considered, but only the top three candidates are listed in this document. The final SBC chosen for the project was the Triton-270 developed by Strategic Test. It was selected primarily for its ultra compact form factor that will allow for maximum flexibility in the design of the daughter card. Strategic Test also offers superior board support packages with their Triton processor modules. The ease of interfacing also had a very heavy influence on the selection of this component. The entire SBC fits in a low profile DIMM 200 form factor. DIMM 200 sockets can be inexpensively obtained. This socket mounted on a PCB will give outstanding versatility for access to the USB and CF/PCMCIA interfaces. It is built around the PXA270 ARM processor. The Triton-270 module is used for rapid prototyping but cheaper PXA255 based modules can be used for production models with the added design requirement of external audio hardware and possibly additional I/O hardware. To be expected, this is also the most expensive option of the lot. While it remains the top choice lack of funding could lead to the selection of a different alternative[4].

The Arcom PC104 Xscale Viper was considered as an alternative. It is a PXA255 based design with AC97 audio built onto the board. The challenge of integrating the human interface devices, display, and interfacing with daughter card hardware ultimately made this a less favorable alternative than the Triton-270 [ref number]

The Compulabs CM-X270W was considered for the benefits and software availability of the PXA270 platform and its compact form factor. It did not offer the simple modularity or the board support of the Triton-270. It also would have had the potential to produce a more unwieldy final design due to its physical interfaces though not as much so as the Arcom Viper. The price for evaluation kits was also less than the Triton series making this a viable last resort alternative[5].

The Compulabs CM-i686M was considered for no other reason than the sheer magnitude of software available for x86 architecture. In the case of the software required for this project, ARM software was as readily available as x86 so it offered none of the traditional x86 software advantages. The ARM architecture is also more mature as an embedded platform and delivered better peripheral I/O integration (e.g. touch screen I/O and PCMCIA) for portable platforms[6].

6.1.2 Wireless Connectivity

Naturally, bandwidth requirements vary according to the number of concurrent network sessions. However the 802.11b standard specified by this project will be adequate for sustaining as many as fifty streams at 128kbps utilizing approximately 7.14Mbps of the available 11Mbps.

Research for the wireless components of the project is still ongoing. The areas of concern when determining suitable components are the avoidance of RF design, the avoidance of BGA type packaging, and GNU/Linux driver support. These are two design areas that cannot be undertaken do to lack of resources and expertise. The highest degree of component integration possible is highly desirable because it sill simplify the design process. At this point, one potential integrated Bluetooth and 802.11 IC

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[4] TRITON-270 Intel XScale PXA270 CPU DIMM embedded SBC module. 3 Dec 2005. <TRITON-270 Intel XScale PXA270 CPU DIMM embedded SBC module>

[5] CM-X270W Computer-On-Module. 13 Nov 2005. <http://www.compulab.co.il/x270/html/x270w-cm-datasheet.htm>

[6] PC104 PXA255 XScale® Single Board Computer. 13 Nov. 2005. <http://www.arcom.com/pc104-xscale-viper.htm>

developed by DPAC has been identified as a candidate component. This device is appealing because it has internal RF components[7]. Bluetooth and 802.11 solutions are made by CSR, Agere, SyChip, and Broadcom. Bluetooth research and part selection is being coordinated with another student team in need of a similar or identical component.

The daughter card will interface using two bus standards. The 802.11 interface will be implemented over PCMCIA or CF. The Bluetooth interface will be implemented over USB. The I/O flexibility of the Triton module will allow the physical interconnects to these buses to mapped to their respective devices using a custom PCB. PCMCIA has a minimum transfer speed of 10MB/s substantially exceeding the necessary bandwidth for 802.11. USB throughput dramatically exceeds the 721 Kbps of Bluetooth.

6.2 Similar Products Currently Available

There are many PDA like devices on the market that would perform similarly to the Itsy. Nearly any PDA with the appropriate wireless connectivity (Bluetooth and 802.11b) options would suffice. several PDAs ship with this functionality built in without the need for additional hardware. A PDA could provide a drop in, though not as cost effective, portable computer hardware solution. Naturally, thin client and server systems are also readily available corporate products. The benefit of this project is derived from the application of the technologies in a manner that addresses potential needs.

6.3 Meetings with Professionals

Corrin Meyer and Gus Velazquez, are acting mentors for our team. Corrin Meyer is a digital design engineer at Smiths Aerospace in Grand Rapids, Michigan. We have had meetings with Corrin regarding the hardware design and fabrication aspects of the project. He has substantial board level design experience and has help provide the team with insight into the challenges of board layout design, and fabrication. Gus Velazquez is a software engineer with L3 Avionics in Grand Rapids, Michigan. He has extensive embedded software design experience and a thorough knowledge of the C programming language, the primary language for the system level software on this project. The need for his expertise and advice has not fully risen, but he will likely play a larger role in advising the project when the software development aspects move to the forefront of our design efforts. Tim Theriault has extensive project management experience at Smith Aerospace in Grand Rapids, Michigan. He has offered advice regarding the some of the managerial challenges any project faces and has also given our team excellent insight into overcoming logistical hurdles, especially those of part procurement and fund acquisition.

7. Project Management

7.1 Team Organization

Senior design is the capstone engineering course at Calvin College. In regards to that, SCT has chosen a team project that meets the design requirements and scope of an undergraduate project. Senior design is structured to reflect the design processes found in the industry. The purpose of senior design is to give the students a taste of what to expect in the workplace. Since the senior design teams have very little experience in industry procedures, each team is paired with an industrial consultant. The industrial consultants are experienced engineers who either are currently working in their field or have done so in the past. They are not affiliated with Calvin and therefore are volunteering their time to Calvin's senior design teams. SCT's industrial consultant is Mr. Tim Theriault who currently works as a department manager at Smiths Aerospace in Grand Rapids, MI. SCT along with all other design teams are required to meet with their industrial consultant once in the fall semester and once more in the spring semester. Since these meetings are few in number the industrial consultant's vision of the design team is solely based on the work they bring to the meetings. This is valuable since it is possible to run into occasions where professors could have biased opinions regarding students. Also because of the objective nature of the meeting SCT brings all necessary and important information and questions to industrial consultant meetings.

Due to the nature of SCT's project the team has invited Jason Roelofs, a computer science major at Calvin College to aid in the software development. SCT requires user level software development which includes but not limited to: SBC user interface software, code for handling the streaming and codec libraries, code for controlling the routing of audio and video streams, and the client/server infrastructure. Jason Roelofs is in charge of his own schedule with deliverable dates corresponding to the completion of the SBC and daughter-card hardware.

Currently, SCT has meeting with its members every week and occasionally with its mentors. The meetings with team mentors are expected to increase in frequency once system design begins in earnest. Meetings involving SCT members are usually informal in nature but have goals that are set out before the meeting is called. Primarily SCT's team meetings have been to discuss project status, project problems and solutions, delegation of tasks and decision making. SCT plans on increasing the frequency of meeting from once a week to a few times each week during interim...

7.2 Project Responsibilities

SCT teams roles have not been defined however, each member have assumed roles where their strengths are applicable as well as where they are needed most. A graphical organization chart can be seen below in figure 5. SCT has defined since the beginning of the project that Ben Bufford would be the team leader. The team lead is ultimately responsible of the progress of the project, deliverables being delivered on time, and communication resolving team dynamic problems. Ben has also been responsible for setting up the team FTP server, where the team stores materials related to the project. Ben is also working on parts procurement, budgeting, research the Itsy and several SBC alternatives, project scheduling, and PPFS documentation. Jermey Gajadhar has done some initial research on PCMCIA, budgeting, parts procurement, research on SBCs, project scheduling and PPFS documentation. Nick Goote has done research on Bluetooth technology, parts procurement, PPFS documentation, and project scheduling. Andrew Oosterhouse has done meeting minutes, more research on PCMCIA, part procurement, research on SBCs, project scheduling and PPFS documentation. In the future, SCT plans to implement a "two-team" approach to system development. One team, comprised of Jermey and Ben, will be responsible for the design, construction, and debugging of the SBC. The second team, comprised of Andrew and Nick, will be responsible for the design, construction, and debugging of the daughter-card. This two-team approach does not mean that the two sub-teams will cease to support each other. The sub-teams will simply spend the majority of their time on their specified focus. If one sub-team needs additional help, the other sub-team will still be available to help.

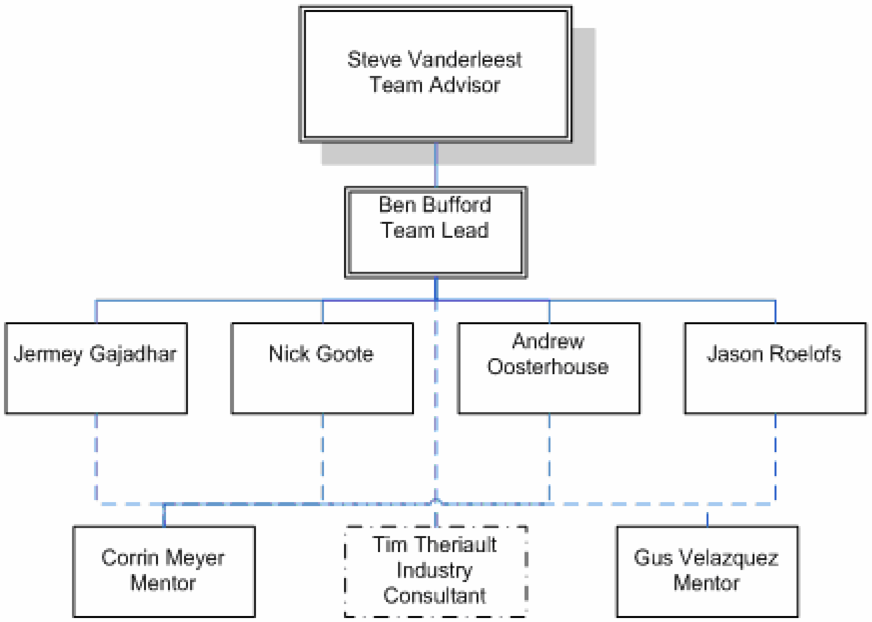

Figure 5 Organizational Chart

7.3 Project Documentation Organization

SCT's project documents are kept primarily on the team FTP server. This server is backed up regularly by Ben and Andrew. Currently Titan is accessible through SSH and FTP software programs with an encrypted username and password protection. Each document is added to Titan under a revision number and placed in appropriate folders. SCT plans to transition to efficient document control software before interim to avoid document overwriting in the case of similar revisions being added to the server at the same time. Although it is highly unlikely to happen, version control software will eliminate this possibility completely..

7.4 Project Timeline

SCT created a project time line using Microsoft Project 2003. The project time line reflects all tasks necessary to complete the project as well as the estimated time required for each project. SCT has assumed a working day of 1 hour per day per team member. This assumption has caused the project schedule to disagree slightly with the amount of hours listed in the task specifications.

Unfortunately SCT has fallen behind schedule. This is due to the slow response from external sources of funding.. This lack of funding, and the subsequent waiting, forced SCT to abandon plans for the Itsy and switch to our SBC contingency plan.. The team has found a SBC that fits our budget and also a few that would produce better results if the team receives any outside funding. SCT is certain that funding will come but it might not be as large scale as initially necessary for the itsy. In light of that, SCT hopes to receive enough money to secure a SBC.

Another problem SCT has hit is schedule reworking. Since the Itsy is not a feasible option, the project schedule must be thoroughly revised to incorporate the new tasks for involved with using the SBC. In using a SBC, it is also possible that the team will experience an increase in required assembly time. SCT has taken all of these issues into consideration and generated the revised schedule summary seen below. A full version of the schedule, with all tasks expanded to their sub-tasks, can be seen in the appendix.

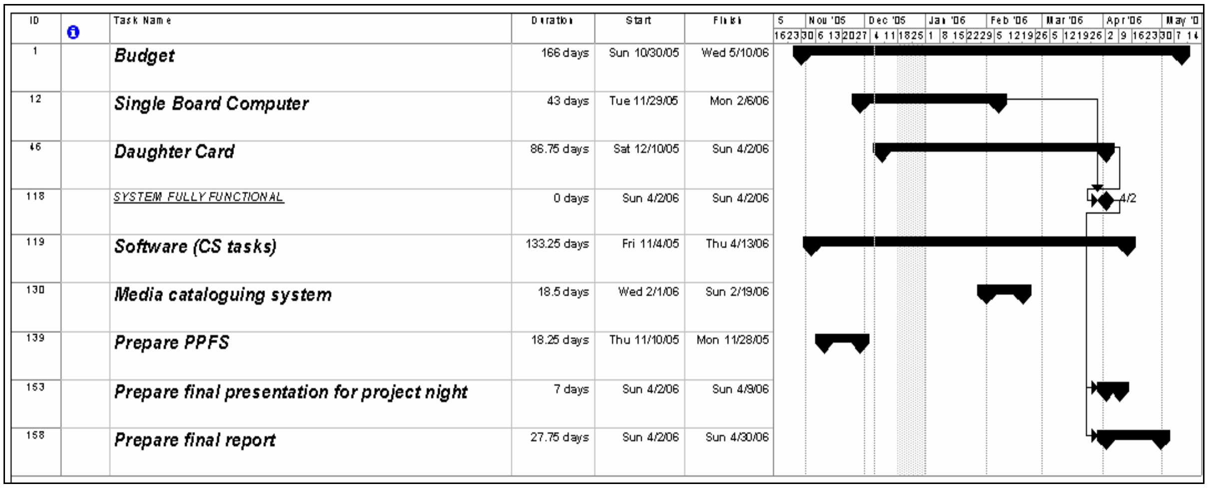

Figure 6-Schedule Summary

7.5 Project Deliverables

SCT shall be accountable for the following deliverables:

1. The engineering team shall supply any ARM based board development system or board no later then the end of interim
2. The engineering team shall also make custom hardware interface specifications by the end of interim.
3. The computer science team shall include regularly scheduled software builds for hardware testing
4. The computer science team shall provide a functional client/server streaming media software delivery by the end of the school year.
5. The initial prototype system shall be completed by May 7th

8. Preliminary Feasibility Analysis

8.1 Media Size Feasibility

SCT has been in contact with Dan Wells, manager of the Cayvan Media area. He has informed us that Cayvan currently has 1913 CD's, 627 DVD's, and 1059 VHS tapes. They also have around 9000 vinyl records and 153 laserdiscs. The current amount of physical space currently used to store this physical media is roughly 300 square feet. This amount of media is equivalent to roughly 6777 GB of data. This is summarized in the table below. This is an enormous amount of data. SCT still believes the project is feasible since we are implementing a proof-of-concept only, and a production server could easily deal with this large size.

Table 2 - Digital Media Size Calculations

	CDs	DVDs	VHS	Vinyl	Laserdisc
# of media	1913	627	1059	9000	153
size (GB)	0.65	6.4	0.5	0.1	0.6
total GB	1243.45	4012.8	529.5	900	91.8
GRAND TOTAL		**6777.55**			

8.2 Cost Estimates

8.2.1 Server and Video terminal Cost estimates

SCT has researched potential server and video terminal technology, and there are a multitude of options available for this technology. For the server, SCT has selected a server which satisfies the requirements with a price tag of $2204.50[8]. The video, which also satisfies the requirements, has a price tag of $498.00[5]

8.2.1.1 Itsy Cost estimates

8.2.1.2 *Prototyping cost estimates*

Currently SCT estimates the grand total of the prototyping to be $4,173.58, as shown in Table 1. This includes parts for three ITSY's, fabrication costs, as well as components for both the ITSY and the daughter card. It is important to note that the budget makes allowances for three ITSY's, but only one daughter card. The reasoning behind this is SCT requires one ITSY for software development, one for daughter card integration, and one for backup. However, only one daughter card is necessary. Since we will be assembling the daughter-card ourselves, we will be able to debug any problems which may arise. A full detailed budget can be seen in Appendix 15.2

Table 3 – ITSY Prototype Cost Estimate

PROTOTYPE BUDGET SUMMARY	
For 1 ITSY	
Itsy Parts	$2,666.98
Itys PCB Fabrication	$366.00
Estimated Assembly costs	$500.00
Video terminal bluetooth interface	$40.00
Bluetooth and 802.11 Dev kits	$1,200.00
GRAND TOTAL	**$4,772.98**

8.2.1.3 *Production Cost estimate*

The production numbers for equipping Hekman library with an IMS system utilizing the ITSY handheld can be seen in the table below. The system which is used in this scenario consists of one Central Media Server, four video terminal systems, and 10 ITSY handhelds.

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[8] Dell Online Store. Dell. 07 Dec 05. <http://ecomm.dell.com/dellstore/basket.aspx?c=us&cs=04&l=en&s=bsd&itemtype=CFG>

Table 4 - ITSY Production Cost Summary

PRODUCTION BUDGET SUMMARY	
For 1 ITSY	
Itsy Parts	$2,666.98
Itys PCB Fabrication	$366.00
Daughter Card Parts	$240.00
Daughter Card PCB Fabrication	$271.00
Estimated Assembly costs	$500.00
Video terminal bluetooth interface	$40.00
Media Server	$2,204.50
Video Terminal	$498.00
TOTAL	**$4,083.98**
Cayvan Media Area	
10 ITSY's	$40,839.77
1 Media Server	$2,204.50
4 Video Terminals	$1,992.00
Grand Total	**$45,036.27**

8.2.2 SBC cost estimates

8.2.2.1 *SBC prototyping costs*

Currently SCT estimates prototyping costs for the SBC system to be $5,087. This budget includes money for one SBC development kit, along with a replacement SBC module for additional development purposes. The budget also includes final assembly parts, along with components needed for daughter-card development and fabrication.

Table 5 - SBC Prototype Cost Estimate

PROTOTYPE BUDGET SUMMARY	
For Portable devices	
Board Support Package	$2,650.00
Additional Module	$366.00
Parts for final Assembly	$600.00
Daughter Card Parts	$100.00
Daughter Card PCB Fabrication	$271.00
Estimated Assembly costs	$500.00
Bluetooth Dev kit	$600.00
GRAND TOTAL	**$5,087.00**

8.2.2.2 *SBC Production costs*

The production numbers for equipping Hekman library with an IMS system utilizing the ITSY handheld can be seen in the table below. The system which is used in this scenario consists of one Central Media Server, four video terminal systems, and 10 ITSY handhelds.

Table 6 - SBC Production Cost Estimate

SBC PRODUCTION BUDGET	
SBC price for 1 modules	$427.50
Parts(5% Break in price)	$570.00
Video terminal bluetooth interface	$40.00
Media Server	$2,204.50
Video Terminal	$498.00
Daughter Card Price(5% Break in price)	$2,850.00
Total for 1 SBCs w/ daughter card	$3,887.50
Cayvan Media Area	
10 SBC's including Daughter Cards	$38,875.00
Media Server	$2,204.50
4 Video Terminals	$1,992.00
Cayvan Media Area Grand Total	**$43,071.50**

8.3 Donations and Funding

Currently, SCT has received a $300 donation from PCB Express, a local board fabrication company. This donation is applicable towards any and all fabrication costs that the team will incur.

SCT has also submitted the detailed project budget to Smiths Aerospace in order to obtain funding. Smiths Aerospace expressed interest in funding our project, and in order to facilitate delivery of funds to the team, requested a budget be submitted to them. SCT is optimistic about receiving funding from Smiths Aerospace, but the team also has contingency plans in place for the project if the funding does not come through

8.4 Overall Feasibility

SCT believes that the project, in one form or another, is feasible. The form of the project will be determined by whether or not funding is obtained from Smiths Aerospace in a timely manner This external funding must be obtained by December 16, 2005 at the latest. Without this external funding, the high cost of the project will make the SBC aspect of the project infeasible.

The first issue SCT considered when analyzing the feasibility of this project was Digital Rights Management (DRM). This is highly important to our project, as DRM will ensure that the media broadcast over the wireless network is not pirated. By extension, this ensures that the Cayvan Media Area does not unknowingly break any copyright laws. SCT has been in contact with David Wells, the Cayvan Media Area manager, who said the incorporation of DRM would be very important for the project to be legally feasible. To this end, SCT will incorporate an open source DRM scheme produced by Sun Microsystems. This system, entitled the DReaM project, will allow SCT to address these DRM concerns without affecting the budget of the project.

The three handheld device alternatives that SCT considered are the ITSY, the Single Board Computer, and a microcontroller circuit. The microcontroller circuit will be a simple circuit based on a microcontroller whose sole purpose is to decode an audio stream. Both the ITSY and the SBC options are intended to be accompanied by the design of a separate daughter-card circuit, which will implement

802.11 wireless Ethernet, along with Bluetooth capabilities. The microcontroller circuit will simply utilize 802.3 wired Ethernet, since designing such a microcontroller circuit will provide the team with ample design work.

The first alternative analyzed was the ITSY handheld computer. It became increasingly clear as the semester went on that this alternative was not feasible because of the time and money required to assemble the system. In addition, fabricating the circuit boards for this device would have also taken another large time commitment. While attractive in concept, the parts were harder to obtain than originally believed. Also, some of the parts were considered obsolete, making them difficult to obtain. Upon completion of board fabrication and assembly, there would be no guarantee that the board would function properly. SCT would then be confronted with the daunting issue of also designing the daughter-card for this device. The time commitment required for daughter-card and ITSY development was far too high, making this alternative infeasible.

The second alternative analyzed was the Single Board Computer. This alternative was more attractive than the ITSY since it helps relieve the time pressure being faced by the team. It also helps to eliminate the quality assurance issues since the SBC is guaranteed to be functional when shipped from the vendor. This alternative also preserves most of the design work involved in the project, since SCT would still be expected to implement 802.11 and Bluetooth into the SBC design, since those capabilities are not natively supported. Overall, the SBC is similarly priced when compared to the ITSY. It turns out that the price of this system is its biggest drawback. Without the assurance of funding from Smiths Aerospace, this alternative is by default infeasible, since SCT cannot afford any of the development equipment on the money allotted by Calvin for senior design projects. If SCT obtains funding from Smiths Aerospace by Dec. 16, this alternative becomes feasible, and indeed the most attractive out of the three.

However, if funding is not obtained, SCT will utilize the microcontroller alternative. This alternative will utilize a microcontroller circuit to decode an audio stream being sent over 802.3 wired Ethernet. This alternative is a last-ditch effort to maintain roughly the same amount of design work while spending only what is allotted by Calvin College. However, the reaction of Smiths to our initial budget was positive, which led the team to believe Smiths will fund the project. The only reason funding has not yet been attained is due to the bureaucratic process in place at Smiths.

Overall, SCT believes that this project, in one form or another, is feasible. A functioning proof-of-concept design will be delivered by May, 2006.

9. Software Design

The software for the project will rely on the GNU/Linux[9] operating system as a foundation. The graphical framework will be the X11 system[10]. There are three primary software design areas. The operating system level software design will focus on implementing drivers to support the daughter card hardware and any custom hardware required for it to correctly interface with the SBC. The client-server design will focus on the control and data transfer software interfaces between the portable device and the media server, the software control interface from the portable device to the video terminals, and the software control and data transfer interfaces between the media server and the video terminal. The user interface design will be centered on the layout and context specific presentation of the media selection and control graphical interfaces.

The OS level design is practically complete. Since GNU/Linux supported hardware was selected for this project modification of existing drivers to work with the daughter card hardware are all that is expected. The bulk of the software design lies in interfacing and controlling the software of the various

[9] The ARM Linux Project. 15 Oct 2005. <http://www.arm.linux.org.uk/>
[10] The X.org Foundation. 15 Nov 2005. < http://wiki.x.org/wiki/>

subsystems. Most of the software development efforts will involve writing the code that brings all of the separate software packages together to form a cohesive system.

9.1 Open Source and Free Software

There is no way this project would be possible without leveraging existing Open Source and free software resources. Apart from the foundational GNU/Linux and X11 software the primary software resources utilized are VLC[11], The BlueZ[12] Bluetooth protocol stack, Apache[13], PostgresSQL[14], Vorbis[15], DivX[16], and Icecast[17]. BlueZ is simply a collection of drivers and a low level protocol stack for using Bluetooth devices under Linux. The Apache web server can service the data stream requests reducing the need to specifically code server side request handlers. Postgress is a SQL engine that will be used to index the media content on the server. Vorbis is the audio encoding method used for this project. DivX is the video encoding method used for this project. Icecast streams Vorbis media over the networks. VLC is a comprehensive client and server video streaming and playback software suite.

9.2 Connectivity Aspects

As stated, the portable device will rely on 802.11 for steaming media and Bluetooth for video selection. Conventional 802.3 networking methods are not discussed in this section.

9.2.1 802.11

The 802.11 implementation used in this project is based on conventional UNIX sockets.

9.2.2 Bluetooth

There are three distinct models for GNU/Linux Bluetooth connectivity [9]. The specific model chosen will depend on how the daughter card hardware is designed. The first method is the serial model. It essentially appears to the system as a serial device and is accessed in the same manner as any other tty character device in the /dev file system. The second is a network emulation method in which the Bluetooth device is accessed by way of a network sockets programming model. The third model is the Bluetooth file system (BTFS)[18]. This is a file system in userspace (FUSE) model that allows access to Bluetooth hardware using file descriptors. The file system model will require the video terminal to monitor a file descriptor and activate on its modification instead of receiving a data packet as with the serial and network emulation methods.

9.3 Subsystems Overview

Each sub system will make unique use of the software technologies described in this section.

9.3.1 Media Server

The media server will handle most requests using Apache; manage and store media using PostgresSQL; and stream data using Icecast for audio and VLC for video.

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[11] VLC Media Player. 3 Oct. 2005. <http://www.videolan.org/vlc/?>
[12] BlueZ. 5 Dec 2005. <http://www.bluez.org/>
[13] The Apache Software Foundation. 4 Dec 2005. <http://www.apache.org/>
[14] PostgreSQL. 3 Dec 2005. <http://www.postgresql.org/>
[15] The Xiph Open Source Community. 1 Dec 2005. <http://www.vorbis.com/>
[16] Divx.com. 28 Nov 2005. <http://www.divx.com/>
[17] Icecast.org. 4 Dec 2005. <http://icecast.org/>
[18] Bluetooth Filesystem mapping. 3 Dec 2005. <http://www.mulliner.org/bluetooth/btfs.php>

9.3.2 Video Terminal

All video related software will use the X11 graphical environment. The VLC player will be used on the video terminal to playback inbound VLC video streams from the media server, and the BlueZ protocol stack will be used to receive control input from the handheld device. The video terminal will perform Bluetooth SDP scans in five-second intervals to detect portable devices. If a portable device is detected it connects and sends a proximity signal.

9.3.3 Portable Device

The Vorbis media libraries will be used to playback inbound audio streams from the media server. The BlueZ protocol stack will be used to send control data to the video terminal. The GUI will be based on the X11 environment

This is also the only portion of the system with which the end user directly interacts; making the graphical interface design quite important. The GUI will be structured as a context sensitive hierarchy. There will be a main interface that will transition to an audio mode interface or a video mode interface under certain conditions. The two affecting conditions are the Bluetooth status on the portable device and – given Bluetooth is active – proximity signal from the video terminal. Bluetooth may be disabled to conserve power on the portable device. If it is inactive, audio mode has been selected by the user. If Bluetooth is active the main interface will transition to the video interface automatically after receiving a proximity signal from the video terminal.

9.4 High Level Algorithms

The general implementation of each major software subsystem is outlined algorithmically in this section.

9.4.1 Portable Device/Video Terminal handshaking and video stream initialization

The first three line items are not applicable if Bluetooth is inactive on the handheld device.

- Portable device receives proximity signal from video terminal
- Portable device sends initiation signal over Bluetooth
- Video terminal responds with identifier over Bluetooth
- Portable interface changes to video selection interface
- Portable device obtains video media list from media server
- User selects video
- Portable device sends media identifier to video terminal over Bluetooth
- Video terminal resolves identifier to media location
- Video terminal requests specified stream URI from media server
- Video stream initiated

9.4.2 Portable device audio stream initialization

- User selects audio mode from main interface
- Bluetooth is disabled to conserve power
- Portable device requests audio media list from media server
- After media list is received available choices are displayed
- User selects desired audio
- URI is requested from media server
- Audio stream is initiated

9.4.3 Video Terminal/Portable Device handshaking and video stream initialization

- When idle, perform one SDP broadcast every five seconds
- If a portable device MAC address is detected execute connection procedure

- Once connection is established send proximity signal
- Wait for initiation signal on Bluetooth interface
- When received send terminal ID over Bluetooth interface
- Wait for media identifier to indicate video selection on Bluetooth interface.
- When received resolve identifier to media URI based on video media list on server
- Request URI from server
- Initiate video stream

9.4.4 Server Side Media Request Handling

Apache does most of the client server heavy lifting. It will process and respond to requests for media lists, and it will receive data URI and call the appropriate icecast or VLC backend. In this way the server will be able to encapsulate outbound media within the HTTP layer simplifying the design by forming a universal access method to all media types. Both backends will also be available using their native ports and protocols.

9.5 Software Diagrams

The block diagrams in the following sections exhibit the logical hierarchy of the software design.

9.5.1 Video terminal

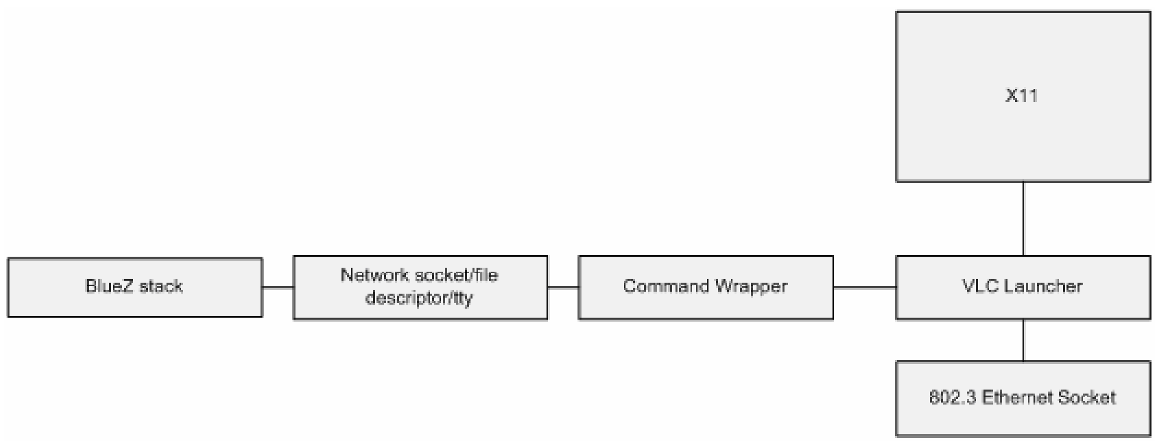

Figure 7 - Portable Device Software Logical Hierarchy

9.5.2 portable device

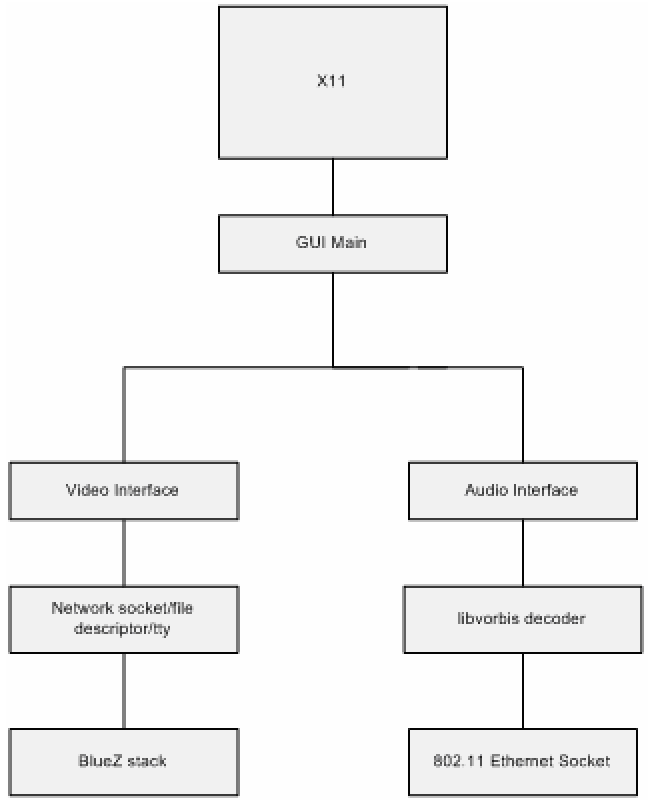

Figure 8 - Video Terminal Software Logical Hierarchy

9.5.3 Media server

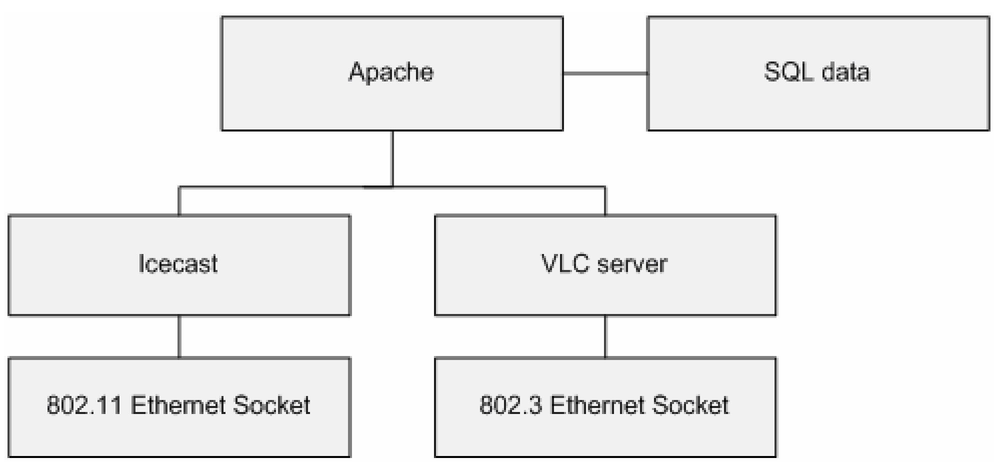

Figure 9 - Media Server Software Logical Hierarchy

10. Project Requirements

Project requirements can be divided up into course requirements, final design requirements, prototype cost requirements, and Timetable and deliverables

10.1 Course Requirements

a. The team shall work efficiently and pay attention to areas where personality types could interfere with the team as a whole
b. The design team shall incorporate necessary and applicable design norms.
c. The design team shall consult a practicing engineer in a directly related field as an industry mentor for the project.
d. The design team shall exercise effective communication in collaboration with a team of computer science students
e. Each design team member is expected to be thorough and punctual in all tasks and assignments

10.2 Final Design Requirements

10.2.1 Physical Requirements

I. Environmental Parameters
   1. The handheld will operate in a temperature range of -20C – 85C, with an optimal operating temperature of 25C-28C
   2. The handheld device shall be built to withstand no greater than 1G of force
   3. The handheld device shall only operate in dry places with built-in static protect

10.2.2 Power Requirements

I. Main power shall be capable of drawing power from a pair of AAA Li-ion rechargeable batteries
II. Power shall be capable of being supplied from a pair of standard AAA alkaline batteries

10.2.3 Hardware Requirements

I. The Single Board Computer
   a. System Board
      i. The SBC shall provide the housing and the interface for the Daughter card add-on
      ii. The SBC shall contain the Intel PXA27x processor with a main crystal frequency of 520MHz
      iii. The SBC shall feature a 200 x 320 pixel LCD touch screen
      iv. The SBC shall include audio options of a microphone, a speaker, and audio jack connector

   b. Daughter Card
      i. The Itsy daughter card shall proved Bluetooth and 802.11 (b/g) functionality
II. Server (proof of concept implementation only)
   General Requirements: The server is not a integral project component; thus it is loosely specified as being any PC class system

i. Intel Pentium III 600MHz or better
ii. 10GB HDD or better
iii. 256MB RAM or better

III. Video Terminal (proof of concept implementation only)
General Requirements: The video terminal is not a integral project component; thus it is loosely specified as being any PC class system
i. Intel Pentium III 600MHz or better
ii. 10GB HDD or better
iii. 256MB RAM or better

10.2.4 Interface Requirements

I. SBC Expansion Interface
  a. There shall be 1 PCMCIA socket available for implementation of Daughter-card wireless feature.
  b. Primary Communication Interface Requirements
    i. The SBC shall access audio and server resources over Ethernet
  c. Secondary Communication Interface Requirements
    i. The handheld shall send Bluetooth control signals to video terminals
  d. Tertiary Physical Communication Interface Requirements (Provided but unused

II. Video Terminal Interface
  a. The video terminal shall play back video media over an Ethernet to the Central Media Server
  b. The video terminal shall signals to control the video playback via Bluetooth. These signals shall be sent from the handheld device.

III. Server Interface
  a. The server shall transmit the requested video media to the video terminal for playback.
  b. The server shall deliver all audio content over wireless Ethernet utilizing the IEEE 802.11 specification.

IV. Software Interface
  a. Inter-device communication shall be implemented using TCP/IP version 4

10.2.5 Software Requirements

I. The SBC with installed Daughter-card
  1. The handheld shall have preinstalled Linux 2.0 Kernel version (possibility of 2.4)
  2. The handheld device shall have an X Windows graphical interface system of either X.org or XFree86, and Basic Windows Manager (e.g. twm), or Gtk.
  3. The unit will be able to recognize streaming media libraries
  4. The handheld device shall require some Ruby programming and use of its libraries

II. Media Server
  1. The media server shall have a Linux 2.6 based Kernel installed.
  2. The server shall also implement a PostgreSQL database engine
  3. Ruby programming shall be a requirement to get the media server functional with the handheld
  4. An Apache 2.0 version shall be installed in order to stream wirelessly with the media server and handheld.

10.2.6 Security and DRM Requirements

I. Digital Rights Management
   a. The IMS will incorporate Sun Microsystem's DReaM DRM scheme.

II. Security
   a. The 802.11 network shall be equipped with WEP or WPA encryption to prevent piracy of the media stream
   b. Access to the central media server shall be restricted to authorized users.

11. System Design

The system design will include a Central Media server, a video terminal, and a handheld device. The system will be scalable, so any number of video terminals and handheld devices can be used, as long as there is sufficient bandwidth. The handhelds will communicate directly with the central media server for the purpose of retrieving audio. The handhelds will also communicate with the video terminals over Bluetooth for the purpose of selecting the correct video media. The server will use 802.11b wireless to stream audio data to the handhelds, and 802.3 wired Ethernet to stream video to the video terminals. The Bluetooth signal will also be used to synchronize the video and audio streams when the handheld is used to watch video media on the video terminal. The system topology can be seen in the figure below.

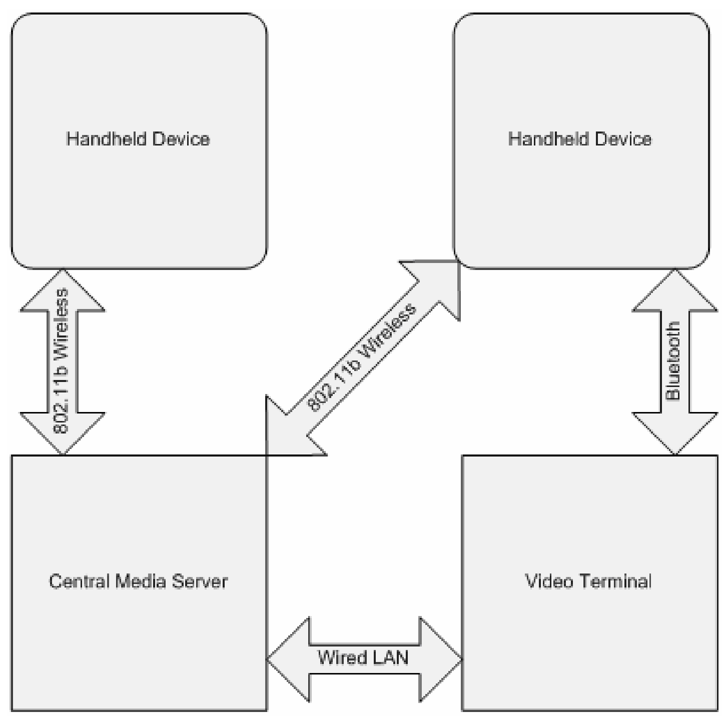

Figure 10 - System topology

11.1 Video Terminal

Thin Client and server feasibility are not critical factors for this project since conventional PCs can be used as drop in replacements to meet the project proof of concept goals. The main purpose of the video terminal is to display video media that is stored on the central media server. The video is delivered to the terminal over a wired Ethernet connection. In essence, the machine used as the video terminal needs to be capable of connecting to an Ethernet network, retrieving video media from the network, and of displaying the retrieved video. Any PC that has these capabilities will be suitable for use as the video terminal.

11.1.1 Criteria

The criteria used to decide on the best implementation for the video terminal includes price, scalability, availability of parts, and ease of use. Of these, SCT deems price to be the most important, since the requirements for a video terminal can be satisfied by a wide range of devices. Scalability is next, followed by availability and ease of use. These criteria are listed in the decision matrix in the table below.

11.1.2 Alternatives

There are two main alternatives for the video terminal implementation. The first is the use of desktop PC's, which has been discussed above. The second alternative is the use of thin client computers. These computers would not be independent computers themselves, but would depend on the central server computer for most of their computational power. In this scenario, the advantage is that the thin client terminals would be cheaper to implement than the desktop PC's. However, the central server would become much more expensive, since it must do most of the processing for each thin client. This arrangement would also severely limit the scalability of the system, since the server would reach its computational limit much faster.

11.1.3 Decision

SCT has decided to recommend the use of standard desktop PC's as the video terminals when the production version of the IMS is implemented. This decision was based on the factors of scalability, availability, and ease of use. The weightings and priorities assigned to each of these factors (and the two alternatives) can be seen in the decision matrix below. Both the weightings and the assigned options are on a scale of 1-10. A higher assigned number indicates an increasing inability of that option to satisfy the criteria. The assigned number is multiplied by the weighting factor, and then added to give a total for each option. The option with the lower total number best satisfies our requirements. The priorities and weightings were assigned according to their importance to the project.

Table 7 - Video Terminal Decision Matrix

Video Terminal	Weighting	Desktop PC's	Thin Client
Price	8	6	7
Scalability	6	2	5
Availability	5	3	4
Ease of Use	5	3	5
Total		90	131

11.2 Server

The Central Media Server is the device which will store all of the digitized media in our system. This device will be responsible for streaming both audio to the handheld device as well as video to the video terminal. SCT believes that a server, which meets the design needs of the project, can be feasibly implemented.

11.2.1 Criteria

Regarding the criteria on which the server options will be based, SCT believes that price is again the most important factor. Available storage is next in importance, due to the large amount of digital media that must be stored on the server. Scalability is important since the system must be able to expand with the number of users. Availability of components is also important, but since all systems are commercially available, this factor is not as important as the others. Finally, the physical space required by the systems is also considered, but is deemed not as important.

11.2.2 Alternatives

There are three main alternatives that SCT considered for the implementation of the server aspect for this project. The first is a standard, high end PC. This option has the advantage of being reasonably priced while delivering acceptable performance and storage. The disadvantage is that the system may not have the scalability that the team desires. Without scalability, this option may cost more in the long run. The second option is to use a small number of lower-end PCs, acting as a single server. The advantages in this scenario are the almost unlimited scalability and low cost. The downside is that this solution will require a large amount of physical space, as well as increased maintenance to make sure the setup works properly. The third option is a standard business server from a retailer such as Dell or IBM. This option has the advantage of being fast, preconfigured, and scalable. The disadvantage in this scenario would be the price. For example, one possible server from Dell would cost roughly $5,000 dollars[19].

11.2.3 Decision

SCT recommends the use of a business server, based on our decision matrix seen in the table below. The priorities were assigned on a scale of 1 to 10, with 10 being the least desirable. Thus, the option with the lowest number is the best choice, according to the priorities and weightings that have been assigned.

Table 8 - Server Decision Matrix

Server	Weighting	Fast PC	Many slower PC's	Business Server
Price	8	6	5	8
Availability	4	6	4	7
Storage	7	5	6	3
Scalability	7	6	4	3
Physical space	3	4	9	3
		161	153	143

11.3 Handheld Device

The handheld device is the device that will control the audio and video streams coming from the Central Media Server. The audio will be streamed directly to the handheld device, while the video will be displayed on a video terminal.

11.3.1 Criteria

The criteria used to judge the different devices include price, availability of parts, fabrication, chance of failure, and expansion capability. Price is again the most important, followed by the expansion capability of the device. Since our project depends on adding capacities to the device, expansion capacity is vital to the project. Next is chance of failure. The devices must be robust and reliable, or maintenance costs will be prohibitively high. This is followed by availability of parts, and required fabrication time.

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[19] Dell Online Store. 6 Dec 2005.
<http://configure.us.dell.com/dellstore/config.aspx?cs=555&oc=PET1800SATAPAD&m_8=80GS&c=us&l=en&s=b>

11.3.2 Alternatives

There are four alternatives to choose from regarding the handheld device. These alternatives include the ITSY, a SBC, and a standard Personal Digital Assistant (PDA). The ITSY offers the largest education opportunity, however, it also requires the most time and money which the team cannot afford. The PDA offers a cheap alternative to the ITSY, but the expansion capability is limited. The SBC offers the required expansion ability, as well as a much lower price. SCT is also considering the use of a microcontroller circuit to decode streaming audio. This option will be used only in the event that funding is not obtained. However, the team is fairly confident that funding will be obtained from Smiths, so this option will most likely not be utilized.

11.3.3 Decision

SCT recommends the use of the SBC for the implementation of this project. Our decision has been documented in the table below. The weightings and priorities were assigned in accordance with the project requirements and facts pertaining to each option.

Table 9 - Handheld Decision Matrix

Handheld	Weighting	ITSY	Single Board Computer	PDA
Price	8	10	3	5
Availability	6	8	5	3
Fabrication/Assembly	5	8	2	3
Chance of Failure	7	8	4	2
Expansion Capability	8	3	4	8
		248	124	151

11.4 Daughter Board

11.4.1 Criteria

The criteria used to judge the desirability of the different daughter-card options are price, size of the parts, reliability, availability, and functionality. Price is the most important, since we hope to implement a cost-effective system. Size and reliability are also important, since the devices must fit into the small space allocated for the daughter-card and still function reliably. Functionality is also important, since we would like the production version of the system to have as much functionality as possible. Finally, availability of parts is also considered, but since all parts are available commercially, this is not as important of a factor.

11.4.2 Alternatives

11.4.2.1 *802.11 Alternatives*

There are three main 802.11 Ethernet alternatives to the daughter-card design that the team had initially envisioned. The first alternative is to use an 802.11 Integrated Circuit (IC) for our wireless Ethernet capability. This option is attractive because of its small physical footprint, as well as the low price of the production version of the IC. However, this option (along with every other 802.11 IC SCT has researched) does not provide sufficient bandwidth for streaming audio applications. The other alternative is to implement a commercially available 802.11 PCMCIA card. These cards are widely available at a fairly low cost. This solution is also highly reliable and offers sufficient bandwidth. The disadvantage is that the card is bigger than the IC under consideration, and their may be royalty issues involved with using a commercial product. The third alternative is simply using a wired Ethernet solution. This solution is attractive since it is reliable and simple, thus easily implemented. This solution is also highly unattractive since using wired Ethernet completely eliminates the portable aspect of the handheld device.

11.4.2.2 *Bluetooth Alternatives*

There are two main Bluetooth alternatives under consideration for use in the final project implementation. The first alternative is the BlueCore Bluetooth chip. This chip is a highly integrated Bluetooth solution. Its advantages include a low price, as well as reliability and high functionality due to its integrated nature. The disadvantage is that the device is a Ball Grid Array (BGA) which means that assembling the device will be more expensive and difficult. The second option is a Bluetooth IC from Amtel. This IC is much smaller with equal functionality to the BlueCore system. It also eliminates the problem of a BGA being involved in the process. However, the Atmel chip is not nearly as highly integrated, and may require additional hardware to function properly.

11.4.3 Decision

SCT recommends the use of a commercially available PCMCIA 802.11 card, combined with the BlueCore system for implementation in the final project. This decision was made based on the criteria outlined above, and is visually depicted in the table below.

Table 10 -Daughter-card Decision Matrix

Daughter-card	Weighting	Wired Ethernet	PCMCIA 802.11 card	DPAC 802.11 IC	BlueCore	Atmel Bluetooth IC
Price	8	3	5	4	3	1
Size	7	4	4	3	2	2
Availability	4	3	3	5	4	4
Reliability	6	4	4	4	4	5
Functionality	6	9	4	6	3	6
		142	128	133	96	104

12. Acknowledgements

First and foremost SCT would like to thank the people who are helping in the project. SCT would like to thank professor Vanderleest of Calvin College for his hard work, encouragement and support. Professor Vanderleest also provided SCT with great feedback and motivation to make the project a success. The team would also like to thank its industrial consultant Tim Theriault from Smiths Aerospace. Mr. Theriault provided realistic ideas and goals to the team as well as reviews of SCT progress. SCT also appreciates the educational opportunity to understand the inner workings of the industrial world. SCT also acknowledges its mentors Corrin Meyer and Gus Velazquez for their specialized help. Corrin Meyer aided the team in the areas of hardware design and layout. Mr. Meyer also provided sound advice on what software layout tools could be used, and also what software problems SCT could face. The team is also grateful for the managerial support that Mr. Velazquez brought to the project. SCT would finally like to acknowledge the hard work of Jason Roelofs, a Computer Science Major.

13. Conclusion

SCT has found that a proof of concept for the Integrated Media System is feasible. SCT has confidence that funding from Smiths will come through soon. In the event that funding is not available, SCT has a contingency plan which calls for using Calvin's budget to fund the proof of concept as shown in the feasibility analysis. In the event that funding does occur, SCT has a defined prototype budget as well as a production budget ready for use. SCT foresees outside funding will take the project one step closer to a production model. SCT plans on having an entire system, including a handheld device with a daughter-card, as well as all necessary software and external hardware, delivered by May 2006.

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15. Appendices

15.1 Prototype budget

Table 11 - Detailed Budget

BUDGET DETAIL						
Part	Part #	Price	Rquired Qty	Min purchase	Seller	Funds required
R=10kOhm RES 10K OHM 1/10W 5% 0603 SMD	MCR03EZPJ103	$0.07	14	10	Digi-Key	$0.97
R=12kOhm RES 12K OHM 1/10W 5% 0603 SMD	MCR03EZPFX1202	$0.07	2	10	Digi-Key	$0.69
R=20kOhm RES 20K OHM 1/10W 5% 0603 SMD	MCR03EZPFX2002	$0.07	1	10	Digi-Key	$0.69
R=30kOhm RES 30K OHM 1/10W 5% 0603 SMD	MCR03EZPFX3002	$0.07	2	10	Digi-Key	$0.69
R=36kOhm RES 36K OHM 1/10W 5% 0603 SMD	MCR03EZPJ363	$0.07	3	10	Digi-Key	$0.69
R=56kOhm RES 56K OHM 1/10W 5% 0603 SMD	MCR03EZPJ563	$0.07	4	10	Digi-Key	$0.69
R=100kOhm RES 100K OHM 1/10W 5% 0603 SMD	MCR03EZPJ104	$0.07	5	10	Digi-Key	$0.69
R=133kOhm RES 133K OHM 1/10W 1% 0603 SMD	MCR03EZPFX1333	$0.08	1	10	Digi-Key	$0.76
R=147kOhm RES 147K OHM 1/10W 1% 0603 SMD	MCR03EZPFX1473	$0.08	1	10	Digi-Key	$0.76
R=2MOhm RES 2M OHM 1/10W 5% 0603 SMD	MCR03EZPJ205	$0.07	2	10	Digi-Key	$0.69
R=Infinite Ohm(22Mohm)	ERJ-3GEYK226V	$0.08	6	10	Digi-Key	$0.80
Augat FSMRA3J SWITCH TACT RA H=3.25MM 160GF	FSMRA	$0.63	2	0	Digi-Key	$1.26
Panasonic EVQ-PLDA15 LIGHT TOUCH SWITCH SMD 100GF 5MM	EVQPL	$0.40	4	0	Digi-Key	$1.58
Augat FSM2JSMA SWITCH TACT 6MM SMD GULL WING	FSMJSMA	$0.45	3	0	Digi-Key	$1.35
Panasonic EVQ-PJX05M SWITCH LT TOUCH 6X3.5 160GF SMD	EVQPJ	$0.39	1	0	Digi-Key	$0.39
DIODE SCHOTTKY 20V 0.5A SOD123	MBR0520LT1	$0.24	1	10	Digi-Key	$2.38
CAP 4700PF 50V CERAMIC X7R 0603	VJ0603Y472KXACW1BC	$0.03	1	10	Digi-Key	$0.29
CAP 6800PF 50V CERAMIC X7R 0603	VJ0603Y682KXACW1BC	$0.06	5	10	Digi-Key	$0.55
CAP 10000PF 50V CERAMIC X7R 0603	C0603C103J5RACTU	$0.08	38	10	Digi-Key	$3.04
CAP CER .015UF 100V X7R 0603	C0603C153K1RACTU	$0.33	2	10	Digi-Key	$3.30
CAP .10UF 16V CERAMIC X7R 0603	VJ0603Y104KXJCW1BC	$0.06	12	10	Digi-Key	$0.76
CAPACITOR TANT 22UF 16V 10% SMD	T491D226K016AS	$0.65	1	1	Digi-Key	$0.65
CAPACITOR TANT 100UF 16V 10% SMD	T491D107K016AS	$1.00	1	1	Digi-Key	$1.00
CAP CER .22UF 16V X7R 10% 0805	C2012X7R1C224K	$0.23	1	10	Digi-Key	$2.30
CAP 1.0UF 16V CERAMIC X7R 0805	C0805C105K4RACTU	$0.18	1	10	Digi-Key	$1.82
CAPACITOR TANT 4.7UF 16V 10% SMD	T491A475K016AS	$0.20	1	1	Digi-Key	$0.20
HOLDER BATTERY 2CELL AAA PC MNT	2468	$0.72	1	10	Digi-Key	$7.24
CAP TANTALUM 15UF 10V 10% SMD	TAJA156K010R	$0.50	16	1	Digi-Key	$8.00
Panasonic EVQ-PJX05M	EVQ-PJX05M	$1.05	1	1	Digi-Key	$1.05
MIC29152BU TR-ND (SEE NOTES IN COLUMN J)	MIC29152BU	$2.27	1	300	Digi-Key	$680.40
SG-8002JC-001.000000M-SCC	SG-8002JC-SCC-ND	$5.88	1	1	Digi-Key	$5.88
SN74LVCH16245ADGGR	296-1244-1-ND	$1.14	1	1	Digi-Key	$1.14
SN74ALVCH16244DGGR	296-1139-1-ND	$1.25	1	1	Digi-Key	$1.25
MC-306	SE2407CT-ND	$0.95	1	1	Digi-Key	$0.95
014 1MM FPC BTM HORZ	AMP 487952-4	$1.28	1	1	Digi-Key	$1.28
CONN RECEPTACLE 8 POS SMD	Hirose 3260-8S1	$2.99	1	1	Digi-Key	$2.99
POT 20K OHM 4MM SQ CERMET SMD	Bourns 3314J-1-203E	$1.44	1	5	Digi-Key	$7.20
POT 500K OHM 4MM SQ CERMET SMD	Bourns 3314J-1-504E	$1.44	1	5	Digi-Key	$7.20
POT 1.0M OHM 1/4" SQ CERM SL ST	Bourns 3362M-1-105	$0.83	1	5	Digi-Key	$4.15
RES 0.0 OHM 1/10W 5% 0603 SMD	R = 0 Ohm x 4	$0.07	4	10	Digi-Key	$0.69

RES .02 OHM 1/4W 1% 1206 SMD	R = 20 mOhm x 3	$1.12	3	1	Digi-Key	$3.36
RESISTOR 1.3 OHM 1/4W 5% 1206	R = 1.3 Ohm	$0.09	10	10	Digi-Key	$0.94
RES 10.0 OHM 1/10W 1% 0603 SMD	R = 10 Ohm	$0.08	1	10	Digi-Key	$0.76
RES 100 OHM 1/10W 1% 0603 SMD	R = 100 Ohm	$0.08	1	10	Digi-Key	$0.76
RES 2.20K OHM 1/10W 1% 0603 SMD	R = 2.2 kOhm	$0.08	1	10	Digi-Key	$0.76
RES 4.7K OHM 1/10W 5% 0603 SMD	R = 4.7 kOhm	$0.07	1	10	Digi-Key	$0.70
TC7SL04FU-TE85L	TC7SL04FUTCT-ND	$0.36	2	1	Digi-Key	$0.72
RES 10K OHM 1/10W 5% 0603 SMD	R = 10 kOhm x 14	$0.07	14	10	Digi-Key	$0.98
Quoted Items (Awaiting return on RFQs)		**Estimated Cost**				
MIC29152BU TR-ND	**QUOTE PENDING**		5		4 star or TBD	$11.34
MAX849ESE	**QUOTE PENDING**		5		4 star or TBD	$19.75
SA-1100	**QUOTE PENDING**		4		4 star or TBD	$200.00
PZ3032-8BC	**QUOTE PENDING**		5		4 star or TBD	$75.00
Am29LV160BB-80REC	**QUOTE PENDING**		5		4 star or TBD	$125.00
Am29LV160BB-80RFC	**QUOTE PENDING**		5		4 star or TBD	$125.00
TC5165165AFTS-50	**QUOTE PENDING**		10		4 star or TBD	$300.00
Sumida CD73-100MC	**QUOTE PENDING**		5		4 star or TBD	$19.75
UCB1200BE	**QUOTE PENDING**		5		4 star or TBD	$19.75
MAX3223CAP	**QUOTE PENDING**		5		4 star or TBD	$19.75
TCM-A0822-22	**QUOTE PENDING**		4		4 star or TBD	$800.00
C = 47 uF thcap	**QUOTE PENDING**		5		4 star or TBD	$19.75
C= 0.33 F supercap	**QUOTE PENDING**		10		4 star or TBD	$39.50
Nais AXK6SA6475P wr160sb	**QUOTE PENDING**		5		4 star or TBD	$25.00
JAE IL-402-22S-S1L-SA ffc22bot	**QUOTE PENDING**		5		4 star or TBD	$25.00
Grayhill 95B04RA SWITCH TACT RT ANGLE FLUSH 240GF	**QUOTE PENDING**		5		4 star or TBD	$25.00
Grayhill 95B12GW	**QUOTE PENDING**		5		4 star or TBD	$25.00
PDI 8499	**QUOTE PENDING**		5		5 star or TBD	$25.00
MiniSIR2	component not required	not purchased	not needed	N/A	N/A	$0.00
Microphone Jack	component not required	not purchased	not needed	N/A	N/A	$0.00
Microphone	component not required	not purchased	not needed	N/A	N/A	$0.00
Speaker	component not required	not purchased	not needed	N/A	N/A	$0.00
Daughter Card Items		**Estimated Cost**				
802.11 Dev kit	**QUOTE PENDING**	$600.00	1		Philips or TBD	$600.00
802.11 IC	**QUOTE PENDING**	$30.00	4		Philips or TBD	$120.00
Bluetooth Dev Kit	**QUOTE PENDING**	$600.00	1		Philips or TBD	$600.00
Bluetooth IC	**QUOTE PENDING**	$30.00	4		Philips or TBD	$120.00
Video Terminal Bluetooth Interface	**QUOTE PENDING**	$40.00	1		Philips or TBD	$40.00

15.2 Processor and Bandwidth calculations

Table 12 Audio Bandwidth and processor Calculations

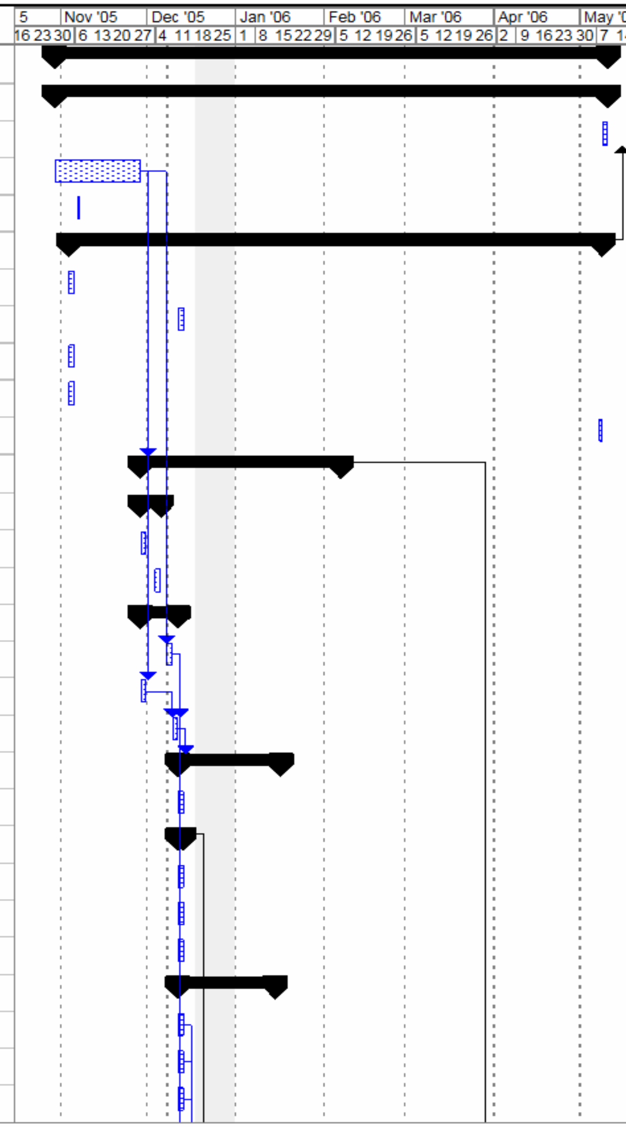
Bandwidth requirements						**processor requirements**		
Audio								
802.11b	BW					44100	samplng rate	
	11Mbps					1024	samples per Vorbis frame	
						0.02321995	sec per frame	
Bitrate	Bitrate including estimated Network Protocol Overhead					Bitrate	cycles/bitrate	minimum clock
64000	76000					64kbps	262135.25	11289223.17
128000	140000					128kbps	524270.5	22578446.34
192000	204000					192kbps	786405.75	33867669.51
256000	268000					256kbps	1048541	45156892.68
Number of streams		64kbs	128kbs	192kbs	256kbs			
5		456000	840000	1224000	1608000			
10		836000	1540000	2244000	2948000			
15		1216000	2240000	3264000	4288000			
20		1596000	2940000	4284000	5628000			
25		1976000	3640000	5304000	6968000			
50		3876000	7140000	10404000	13668000			
100		7676000	14140000	20604000	27068000			
200		15276000	28140000	41004000	53868000			
	%CPU Utilization for each bitrate							
CPU clock	64kbps	128kbps	192kbps	256kbps				
100000000	0.11289223	0.22578446	0.3386767	0.45156893				
200000000	0.05644612	0.11289223	0.16933835	0.22578446				
400000000	0.02822306	0.05644612	0.08466917	0.11289223				
500000000	0.02257845	0.04515689	0.06773534	0.09031379				

Table 13 - Video Bandwidth Calculations

Video						
802.3	BW					
	100Mbps					
Format	Bitrate including Audio		Bitrate including estimated Network Protocol Overhead			
DivX	850000		862000			
VCD	2182000		2194000			
DVD	6548000		6560000			
		Required BW for each format				
Number of streams		DivX	VCD	DVD		
5		5172000	13164000	39360000		
10		9482000	24134000	72160000		
15		13792000	35104000	104960000		

15.3 Detailed Project Schedule

ID	Indicators	Task Name	Duration	Start	Finish	Predecessors
1		***Budget***	**166 days**	**Sun 10/30/05**	**Wed 5/10/06**	
2		**Obtain external funding.**	**166 days**	**Sun 10/30/05**	**Wed 5/10/06**	
3	▦	Submit Proposal/Budget to Smiths	2 days	Tue 5/9/06	Wed 5/10/06	6
4	▦	Budget approval (From Smiths: includes acqusition of funds)	30 days	Sun 10/30/05	Mon 11/28/05	
5	▦	Contact PCB Express for donations	1 day	Mon 11/7/05	Mon 11/7/05	
6		**Produce detailed budget for handheld and daughtercard**	**159 days**	**Fri 11/4/05**	**Mon 5/8/06**	
7		Produce detailed Itsy Budget	2 days	Fri 11/4/05	Sat 11/5/05	
8	▦	Produce detailed SBC Budget	2 days	Mon 12/12/05	Tue 12/13/05	
9		Produce detailed daughtercard Budget	2 days	Fri 11/4/05	Sat 11/5/05	
10		Produce production Budget	2 days	Fri 11/4/05	Sat 11/5/05	
11	▦	Periodically revise Budget	1 day	Mon 5/8/06	Mon 5/8/06	
12		***Single Board Computer***	**43 days**	**Tue 11/29/05**	**Mon 2/6/06**	**4**
13		***Feasibility***	**7 days**	**Tue 11/29/05**	**Mon 12/5/05**	
14	▦	Determine interface possibilities	2 days	Tue 11/29/05	Wed 11/30/05	
15	▦	Determine tools required	2 days	Sun 12/4/05	Mon 12/5/05	
16		***Assembly***	**13 days**	**Tue 11/29/05**	**Sun 12/11/05**	
17	▦	Procure digikey parts	2 days	Thu 12/8/05	Fri 12/9/05	4
18		Procure obsolete parts	2 days	Tue 11/29/05	Wed 11/30/05	4
19		Assemble parts	2 days	Sat 12/10/05	Sun 12/11/05	17,18
20		***Software (EE tasks)***	**16 days**	**Mon 12/12/05**	**Mon 1/16/06**	**19**
21		Compile and install Operating System	2 days	Mon 12/12/05	Tue 12/13/05	
22		**Find necessary device drivers**	**2 days**	**Mon 12/12/05**	**Tue 12/13/05**	
23		Examine Linux Kernel for native device support	2 days	Mon 12/12/05	Tue 12/13/05	
24		Search for premade open source drivers	2 days	Mon 12/12/05	Tue 12/13/05	
25		Research implementation of premade drivers	2 days	Mon 12/12/05	Tue 12/13/05	
26		**Design necessary device drivers**	**14 days**	**Mon 12/12/05**	**Sat 1/14/06**	
27		Research programming of device drivers	2 days	Mon 12/12/05	Tue 12/13/05	
28		Search for device driver examples	2 days	Mon 12/12/05	Tue 12/13/05	
29		Search for similar device drivers	2 days	Mon 12/12/05	Tue 12/13/05	



Project: schedule(prelim)
Date: Thu 12/8/05

Task	░░░	Milestone	◆	External Tasks	▬
Split	······	Summary	▬	External Milestone	◆
Progress	▬	Project Summary	▬	Deadline	⇩

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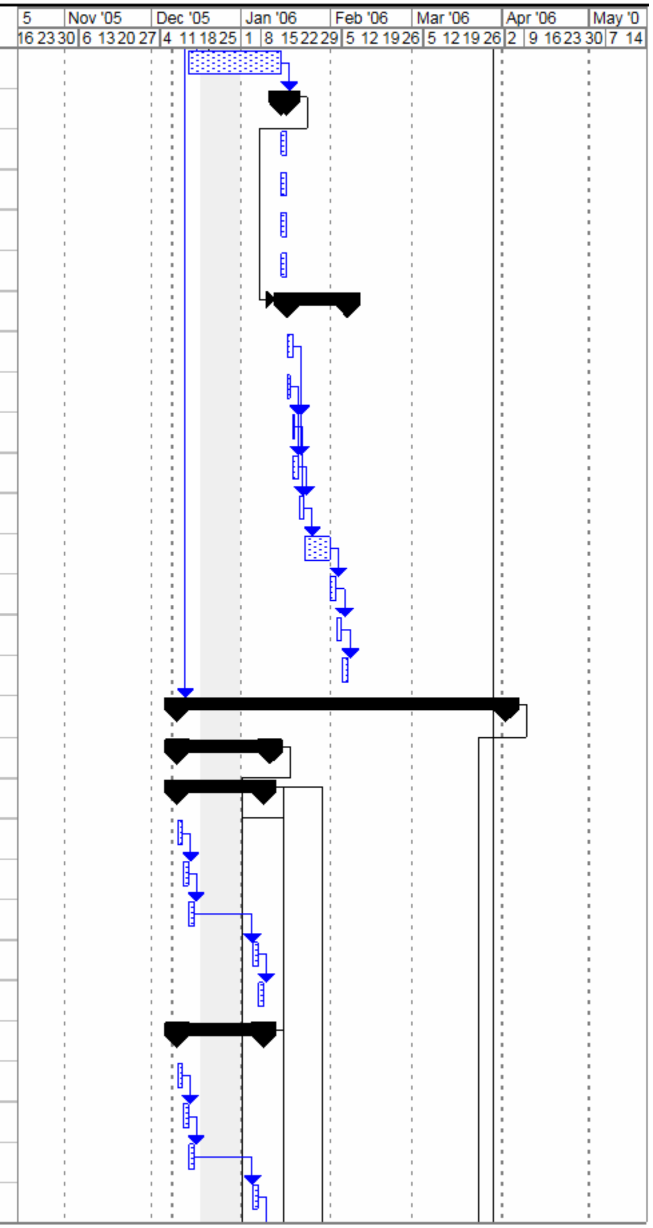
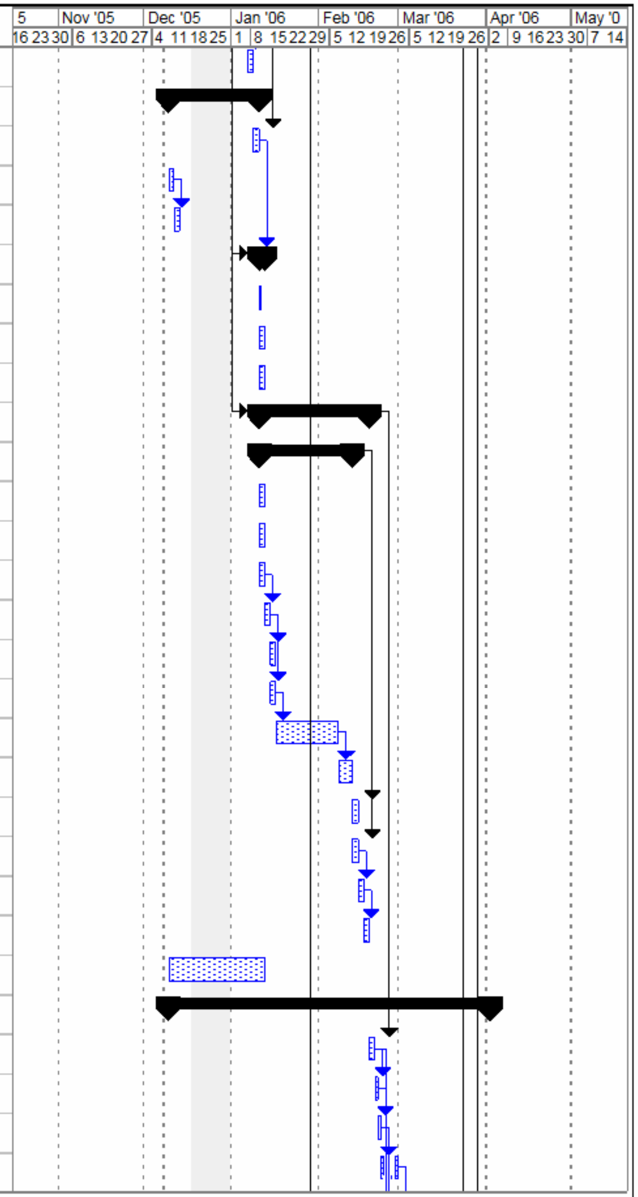
ID		Task Name	Duration	Start	Finish	Predecessors
30		Program device drivers	12 days	Wed 12/14/05	Sat 1/14/06	22,27,28,29
31		**Debug any OS or driver related problems**	**2 days**	**Sun 1/15/06**	**Mon 1/16/06**	**30**
32		Debug OS related problems	2 days	Sun 1/15/06	Mon 1/16/06	
33		Debug driver installation problems	2 days	Sun 1/15/06	Mon 1/16/06	
34		Debug driver compiled problems	2 days	Sun 1/15/06	Mon 1/16/06	
35		Debug driver functionality problems	2 days	Sun 1/15/06	Mon 1/16/06	
36		***Testing and Debugging***	**14 days**	**Tue 1/17/06**	**Mon 2/6/06**	**31**
37		Identify requirements to be tested	2 days	Tue 1/17/06	Wed 1/18/06	
38		Identify additional tests	1 day	Tue 1/17/06	Tue 1/17/06	
39		Write test checklist	0.5 days	Thu 1/19/06	Thu 1/19/06	37,38
40		Identify/procure test equipment needed	2 days	Thu 1/19/06	Fri 1/20/06	37,38
41		Run driver tests	2 days	Sat 1/21/06	Sun 1/22/06	39,40
42		Run handheld tests	2 days	Mon 1/23/06	Tue 1/31/06	41
43		Document test results	2 days	Wed 2/1/06	Thu 2/2/06	42
44		Debug problems	2 days	Fri 2/3/06	Sat 2/4/06	43
45		Re-run tests	2 days	Sun 2/5/06	Mon 2/6/06	44
46		***Daughter Card***	**86.75 days**	**Sat 12/10/05**	**Sun 4/2/06**	**17**
47		***Research necessary components***	**12 days**	**Sat 12/10/05**	**Tue 1/10/06**	
48		**Research Bluetooth hardware and software**	**10 days**	**Sat 12/10/05**	**Sun 1/8/06**	
49		Research ICs	2 days	Sat 12/10/05	Sun 12/11/05	
50		Research development kits	2 days	Mon 12/12/05	Tue 12/13/05	49
51		Research bluetooth software	2 days	Wed 12/14/05	Thu 12/15/05	50
52		Analyze options	2 days	Thu 1/5/06	Fri 1/6/06	51
53		Select solution	2 days	Sat 1/7/06	Sun 1/8/06	52
54		**Research 802.11 hardware and software**	**10 days**	**Sat 12/10/05**	**Sun 1/8/06**	
55		Research ICs	2 days	Sat 12/10/05	Sun 12/11/05	
56		Research development kits	2 days	Mon 12/12/05	Tue 12/13/05	55
57		Research bluetooth software	2 days	Wed 12/14/05	Thu 12/15/05	56
58		Analyze options	2 days	Thu 1/5/06	Fri 1/6/06	57



Project: schedule(prelim)
Date: Thu 12/8/05

Task | Split | Progress | Milestone | Summary | Project Summary | External Tasks | External Milestone | Deadline

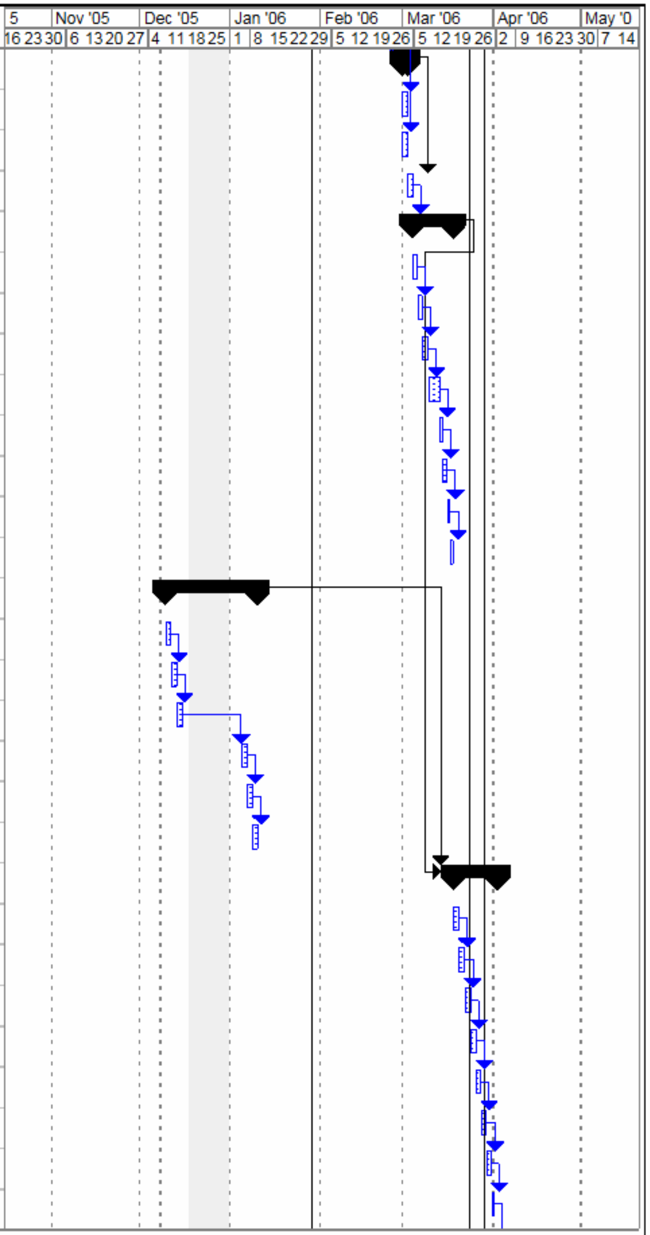
ID		Task Name	Duration	Start	Finish	Predecessors
59		Select solution	2 days	Sat 1/7/06	Sun 1/8/06	58
60		**Research power requirements and implementation of daughter-c**	**12 days**	**Sat 12/10/05**	**Tue 1/10/06**	
61		Research power requirements	2 days	Mon 1/9/06	Tue 1/10/06	54,48
62		Research possible interfaces	2 days	Sat 12/10/05	Sun 12/11/05	
63		Choose best interface	2 days	Mon 12/12/05	Tue 12/13/05	62
64		***Research board fabrication***	**2 days**	**Wed 1/11/06**	**Thu 1/12/06**	**48,61**
65		Research trace length/width requirements	1 day	Wed 1/11/06	Wed 1/11/06	
66		Research number of required board layers	2 days	Wed 1/11/06	Thu 1/12/06	
67		Research local board fabricators	2 days	Wed 1/11/06	Thu 1/12/06	
68		***Schematic Design***	**32 days**	**Wed 1/11/06**	**Sat 2/18/06**	**47**
69		**CAD software**	**26 days**	**Wed 1/11/06**	**Sun 2/12/06**	
70		Analyze different CAD options	2 days	Wed 1/11/06	Thu 1/12/06	
71		Test different options	2 days	Wed 1/11/06	Thu 1/12/06	
72		Choose best option	2 days	Wed 1/11/06	Thu 1/12/06	
73		Software tutorials	2 days	Fri 1/13/06	Sat 1/14/06	72
74		Practice PCB design	2 days	Sun 1/15/06	Mon 1/16/06	73
75		Practice schematic design	2 days	Sun 1/15/06	Mon 1/16/06	73
76		Design daughtercard	15 days	Tue 1/17/06	Tue 2/7/06	75
77		Layout daughtercard on PCB	5 days	Wed 2/8/06	Sun 2/12/06	76
78		Identify relevant requirements	2 days	Mon 2/13/06	Tue 2/14/06	69
79		Obtain simulation software	2 days	Mon 2/13/06	Tue 2/14/06	69
80		Run necessary simulations	2 days	Wed 2/15/06	Thu 2/16/06	79
81		Have schematic reviewed by Corrin	2 days	Fri 2/17/06	Sat 2/18/06	80
82		Send board out for fabrication	14 days	Sat 12/10/05	Thu 1/12/06	
83		***Test and debug board***	**86.75 days**	**Sat 12/10/05**	**Sun 4/2/06**	
84		Identify requirements to be tested	2 days	Sun 2/19/06	Mon 2/20/06	68
85		Identify additional tests	1 day	Tue 2/21/06	Tue 2/21/06	84
86		Write test checklist	1 day	Wed 2/22/06	Wed 2/22/06	85
87		Identify/procure test equipment needed	2 days	Thu 2/23/06	Tue 2/28/06	86



Project: schedule(prelim)
Date: Thu 12/8/05

Task	Milestone	External Tasks
Split	Summary	External Milestone
Progress	Project Summary	Deadline

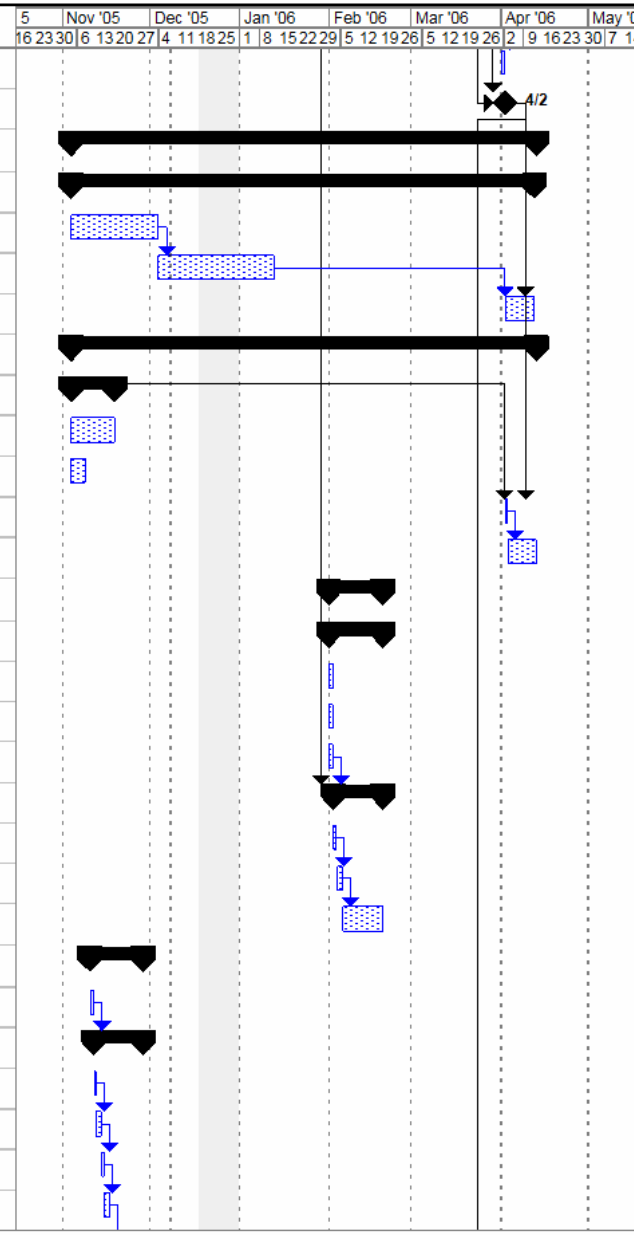
ID	Task Name	Duration	Start	Finish	Predecessors
88	**Run tests**	**2 days**	**Wed 3/1/06**	**Thu 3/2/06**	**84,85,86**
89	Run IC test	2 days	Wed 3/1/06	Thu 3/2/06	87
90	Perform continuity test	2 days	Wed 3/1/06	Thu 3/2/06	87
91	Document test results	1.5 days	Fri 3/3/06	Sat 3/4/06	88
92	**Debug problems**	**14 days**	**Sat 3/4/06**	**Sat 3/18/06**	**91**
93	Identify problems	1.75 days	Sat 3/4/06	Mon 3/6/06	
94	Design test to isolate problems	1.75 days	Mon 3/6/06	Tue 3/7/06	93
95	Test isolated problems	2 days	Wed 3/8/06	Thu 3/9/06	94
96	Repair problems	4 days	Fri 3/10/06	Mon 3/13/06	95
97	Document repair	1 day	Tue 3/14/06	Tue 3/14/06	96
98	Update schematic	1.5 days	Wed 3/15/06	Thu 3/16/06	97
99	Document test results	1 day	Thu 3/16/06	Fri 3/17/06	98
100	Rerun tests	1 day	Fri 3/17/06	Sat 3/18/06	99
101	**Design daugthercard to handheld interface**	**11.75 days**	**Sat 12/10/05**	**Tue 1/10/06**	
102	Identify interface options	2 days	Sat 12/10/05	Sun 12/11/05	
103	Analyze advantages of each option	2 days	Mon 12/12/05	Tue 12/13/05	102
104	Choose best option	2 days	Wed 12/14/05	Thu 12/15/05	103
105	Design interface based on best option	2 days	Thu 1/5/06	Fri 1/6/06	104
106	Test interface	2 days	Sat 1/7/06	Sun 1/8/06	105
107	Implement interface	1.75 days	Mon 1/9/06	Tue 1/10/06	106
108	**Test and debug combined system**	**15.25 days**	**Sat 3/18/06**	**Sun 4/2/06**	**92,101**
109	Define tests	2 days	Sat 3/18/06	Mon 3/20/06	
110	Run tests	2 days	Mon 3/20/06	Wed 3/22/06	109
111	Document results	2 days	Wed 3/22/06	Fri 3/24/06	110
112	Isolate problems	1.75 days	Fri 3/24/06	Sun 3/26/06	111
113	Test isolated problems	1.75 days	Sun 3/26/06	Mon 3/27/06	112
114	Repair problems	2 days	Tue 3/28/06	Wed 3/29/06	113
115	Document results	1.5 days	Thu 3/30/06	Fri 3/31/06	114
116	Rerun tests	1 day	Fri 3/31/06	Sat 4/1/06	115



Project: schedule(prelim)
Date: Thu 12/8/05

Task · Split · Progress · Milestone · Summary · Project Summary · External Tasks · External Milestone · Deadline

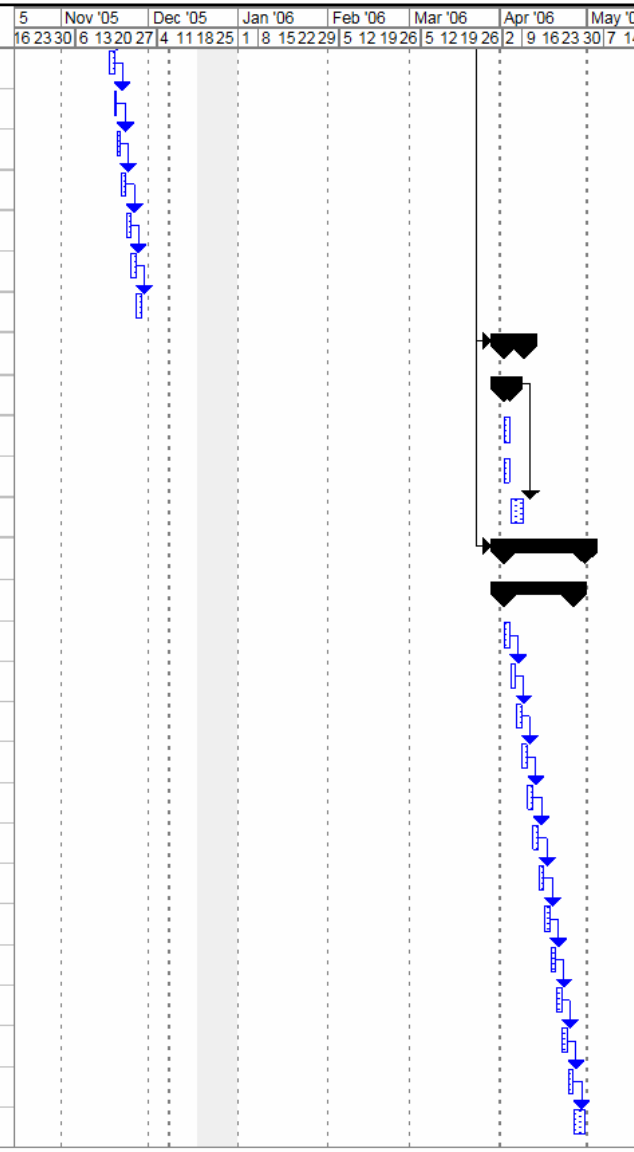
ID	Indicators	Task Name	Duration	Start	Finish	Predecessors
117		Update schematic	1.25 days	Sat 4/1/06	Sun 4/2/06	116
118		***SYSTEM FULLY FUNCTIONAL***	**0 days**	**Sun 4/2/06**	**Sun 4/2/06**	**12,46**
119		***Software (CS tasks)***	**133.25 days**	**Fri 11/4/05**	**Thu 4/13/06**	
120		**Media Cataloging system**	**132.75 days**	**Fri 11/4/05**	**Wed 4/12/06**	
121		Design custom interface software for thin client/server interface	30 days	Fri 11/4/05	Sat 12/3/05	
122		Debug and test custom software	20 days	Sun 12/4/05	Thu 1/12/06	121
123		Implement custom software	10 days	Sun 4/2/06	Wed 4/12/06	122,118
124		**Handheld Software**	**133.25 days**	**Fri 11/4/05**	**Thu 4/13/06**	
125		**Design and complie custom software**	**15 days**	**Fri 11/4/05**	**Fri 11/18/05**	
126		SBC media selection software	15 days	Fri 11/4/05	Fri 11/18/05	
127		Thin client software	5 days	Fri 11/4/05	Tue 11/8/05	
128		Upload custom software	0.5 days	Sun 4/2/06	Mon 4/3/06	125,118
129		Debug custom software problems	10 days	Mon 4/3/06	Thu 4/13/06	128
130		***Media cataloguing system***	**18.5 days**	**Wed 2/1/06**	**Sun 2/19/06**	
131		**EE Task**	**18.5 days**	**Wed 2/1/06**	**Sun 2/19/06**	
132		Catalogue audio and video	1.25 days	Wed 2/1/06	Thu 2/2/06	
133		Procure thin client terminal	1.25 days	Wed 2/1/06	Thu 2/2/06	
134		Procure server computer	1.25 days	Wed 2/1/06	Thu 2/2/06	
135		**Obtain bluetooth cards**	**17.25 days**	**Thu 2/2/06**	**Sun 2/19/06**	**48,134**
136		Select vendor	1.25 days	Thu 2/2/06	Fri 2/3/06	
137		Decide on card	2 days	Fri 2/3/06	Sun 2/5/06	136
138		Procure cards	14 days	Sun 2/5/06	Sun 2/19/06	137
139		***Prepare PPFS***	**18.25 days**	**Thu 11/10/05**	**Mon 11/28/05**	
140		Write detailed table of contents	1.25 days	Thu 11/10/05	Fri 11/11/05	
141		**Write PPFS**	**17 days**	**Sat 11/12/05**	**Mon 11/28/05**	**140**
142		Write Introduction/conclusion	0.75 days	Sat 11/12/05	Sat 11/12/05	
143		Write Educational and Design Objective	1.5 days	Sat 11/12/05	Mon 11/14/05	142
144		Write Design Norms	1 day	Mon 11/14/05	Tue 11/15/05	143
145		Write Project task list and time allocation	2 days	Tue 11/15/05	Thu 11/17/05	144



Project: schedule(prelim)
Date: Thu 12/8/05

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	

ID		Task Name	Duration	Start	Finish	Predecessors
146		Write Research section	2 days	Thu 11/17/05	Sat 11/19/05	145
147		Write Project Management	1.25 days	Sat 11/19/05	Sun 11/20/05	146
148		Write Team Organization	1.25 days	Sun 11/20/05	Mon 11/21/05	147
149		Write Preliminary Feasibility Analysis	2 days	Mon 11/21/05	Wed 11/23/05	148
150		Write Software Design	1.25 days	Wed 11/23/05	Thu 11/24/05	149
151		Write Project Requirements	2 days	Fri 11/25/05	Sat 11/26/05	150
152		Write System Design	2 days	Sun 11/27/05	Mon 11/28/05	151
153		***Prepare final presentation for project night***	**7 days**	**Sun 4/2/06**	**Sun 4/9/06**	**118**
154		**Write presnteation**	**2 days**	**Sun 4/2/06**	**Tue 4/4/06**	
155		Write project night presentation	2 days	Sun 4/2/06	Tue 4/4/06	
156		Write final class presentation	1.75 days	Sun 4/2/06	Tue 4/4/06	
157		Rehearse presentataion	5 days	Tue 4/4/06	Sun 4/9/06	154
158		***Prepare final report***	**27.75 days**	**Sun 4/2/06**	**Sun 4/30/06**	**118**
159		**Write final report**	**24 days**	**Sun 4/2/06**	**Wed 4/26/06**	
160		Write chapter 1	2 days	Sun 4/2/06	Tue 4/4/06	
161		Write chapter 2	2 days	Tue 4/4/06	Thu 4/6/06	160
162		Write chapter 3	2 days	Thu 4/6/06	Sat 4/8/06	161
163		Write chapter 4	2 days	Sat 4/8/06	Mon 4/10/06	162
164		Write chapter 5	2 days	Mon 4/10/06	Wed 4/12/06	163
165		Write chapter 6	2 days	Wed 4/12/06	Fri 4/14/06	164
166		Write chapter 7	2 days	Fri 4/14/06	Sun 4/16/06	165
167		Write chapter 8	2 days	Sun 4/16/06	Tue 4/18/06	166
168		Write chapter 9	2 days	Tue 4/18/06	Thu 4/20/06	167
169		Write chapter 10	2 days	Thu 4/20/06	Sat 4/22/06	168
170		Write chapter 11	2 days	Sat 4/22/06	Mon 4/24/06	169
171		Write chapter 12	2 days	Mon 4/24/06	Wed 4/26/06	170
172		Proofread final report	3.75 days	Wed 4/26/06	Sun 4/30/06	171



Project: schedule(prelim)
Date: Thu 12/8/05

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	