UNIVERSITY OF PUERTO RICO AT MAYAGUEZ

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

AeroBal: An Automated Wind Tunnel

A PROJECT PROPOSAL SUBMITTED AS A PARTIAL REQUIREMENT OF THE COMPUTER ENGINEERING PROJECT DESIGN COURSE ICOM-5047

by:

Anthony Llanos - Project Manager

Juan J. Lebrón

Manuel E. Márquez

Jesús E. Luzón

For: Professors Nayda Santiago, Jose Fernando Vega, and Kejie Lu

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Executive Summary

Wind tunnels are ~~devices~~ used to study the aerodynamic characteristics of objects under the effect of air in motion. Characteristics ~~that can be~~ studied include a number of physical quantities, such as drag, lift, and side. These ~~three~~ are forces exerted by the air in three dimensional space, one for each component. The tunnel measures these by pulling ~~(for laminar flow)~~ air into the tunnel and having ~~a~~ device that measures th~~is~~ force on the object. At the University of Puerto Rico at Mayaguez, Department of Civil Engineering, the tunnel uses a balance that mechanically ~~allows measurement of~~ these forces~~, and thus the process is very manual~~. At the Microprocessor Interfacing course, the team had the opportunity to develop a electronic alternative that automates this process for two forces~~ that were being measured (~~drag and lift~~)~~. ~~However it was all done as a prototype~~ for the course. The objective of ~~the~~ project is to move from prototype to complete implementation of the ~~project~~ ~~by~~ adding new and ~~perfecting~~ existing components.

Both hardware and software have to be improved to ensure the quality of the project. On the hardware side the project must ~~achieve the~~ control~~ling of~~ the drive that limits the pull of air of a room sized motor, the feedback control algorithm that ~~allows the adjustment of~~ the speed ~~of the air of~~ the tunnel, the signal ~~conditioning of~~ the components that measure the forces, and ~~include~~ the third component ~~for measurement~~ the side. On the software side, the data is not being stored ~~or process to provide more statistical or analytical data~~ about the experiments~~ run~~. Historical data can be provided by implementing an architecture that stores data by model, and provides this statistical and analytical data about the model. Models can have this data along with their design and therefore can be shared with the community for collaborative study~~ for continuous improvement~~. Hence an application that shows the progress of the experiment and automatically shows the history and all data can be implemented to achieve these goals. ~~This requires a robust design of an architecture to connect these modules together and provide a good easy to use interface for the user.~~
The project will be develop ~~for~~ 13 weeks in the facilities of the university and the end goal is to have a fully developed and deployed system~~ that provides reliable results~~. It will be used ~~by those~~ courses ~~that require them such as~~ Civil Engineering and Mechanical Engineering. ~~No training, contrary to the present situation, will be required since the design of the system is user friendly.~~ ~~The budget~~ for the system is provided by the client, Dr. Zapata, ~~who will provide necessary components for deployment.~~ The end date of the project is May 6th.

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1. Problem Statement

Wind tunnels are mechanisms used for analyzing the aerodynamic properties of objects, that is, how these objects interact with air in motion. The mechanism simulates air in motion and the effect on the object is measured using a device that intercepts the forces caused by the air. These forces/components are denoted drag, lift and side. The drag is the horizontal force parallel to the direction of the air, lift is the vertical force, and side is the rotation about the vertical axis~~.~~, ~~making the measurement be in three-dimensional space~~.

The Civil Engineering Department of the University of Puerto Rico, Mayaguez Campus [1] has a small wind tunnel used for research. It was built around 1983 and since then has not been renewed to use new technology that may improve the experiments conducted with it. The component that measures the forces, the balance, has a design that is completely mechanical and requires manual measurement of forces. Sensor data from the experiments such as temperature, humidity, pressure, and others are also measured manually.

Setting an initial position using weight without the tunnel being turned on, uses the current mechanical balance. Once the tunnel is turned on, the balance will go out of its initial position. Weight is used to return the balance to its initial position and it is placed by component (currently drag and lift only). Only the weight added in each component is then measured using a scale, and these weights represent the amount of force caused by the air.

Last semester, Anthony, Jesus and Juan [2] ~~had the opportunity of~~ work~~ing~~ in the Microprocessor Interfacing course on this problem and successfully implemented a design of the balance that used strain gauges ~~as the component~~ to measure forces, added the third component to the design, the side, ~~currently not being measured in the facility's tunnel,~~ and implemented the basis for using electronic sensors ~~that substituted those manually measured at the facility~~ ~~(~~temperature, humidity, barometric pressure, wind speed~~)~~.

The project while successful ~~in its~~ proof ~~on~~ concept and minimal conception, requires installation in the facility as it was developed in a prototype tunnel. Installation ~~may require~~

changing the design of ~~old~~ components to be adjusted to the facility and new components ~~to be designed~~ to complete the design and provide additional functionality.

1.1 Installation

Aside from designing a new base for the balance, the ~~already implemented~~ sensors have to be placed in the tunnel. A PCB will be designed to create a compact, clean, and organized solution that is robust and stable. The signals received from the measurement of forces require conditioning to eliminate noise. A power management unit has to be implemented according to the voltage levels used in the implementation, which was previously provided by independent MCUs used as power supplies.

1.2 Expansion

In order to complete the project, additional components ~~may~~ be implemented to allow easier interaction with the current design. The current software design stores data in files, but does not provide visualization ~~of said data~~ or additional data such as statistical data ~~(except for average)~~ or other calculations ~~of properties~~ that can be added to the ~~software~~. Storage of data in files provides only individual analysis and if cumulative analysis is desired, it must be manually performed. Expanding the software to include these features may be accomplished using a database ~~that stores this data~~, and implementing the appropriate software modules. This software ~~can~~ include a user interface that has the option to use ~~it either~~ in a computer or a tablet. At the same time, an account control may be implemented to allow ~~for~~ multiple users ~~to~~ access ~~their~~ data remotely and use ~~said~~ data history for their experiments. The third force component, the side, must be integrated into measurements in the software. Data could also be delivered to other remote ~~individuals~~ that desire to compare results.

As for hardware design, an interface for the motor that controls the speed of the wind in the tunnel must be implemented as well as the algorithm that allows the adjustment of this speed. A module ~~to acquire a images~~ of the object is proposed such that the reference data of the object ~~being studied~~ can be stored along with the data captured.

2. Project Objectives

- Final Development, integration and installation of the Microprocessor Interfacing course project, AeroBal, in the Civil Engineering Faculty by May 5th, 2014.
- Extend this project to achieve the following new objectives.
    - Implement a robust application structure to control the system from two different devices a tablet and a PC.
    - Create a repository ~~from~~ data acquired via experiments conducted in the tunnel and provide visualization, statistical and analysis tools of the data.
    - Make the repository accessible to scientific community via a web dashboard running from data server.
    - Provide a mechanism that nurtures the exchange of ideas and the communication between scientists in this field.
    - Implement side component force measurement ~~hardware~~.
    - Implement additional pressure sensor for wind speed calculations.
    - Implement controller circuits for fan and wind speed windows actuator.
    - Implement signal conditioning techniques.
    - Implement additional communication interface between microcontroller and server.
    - Refine previous microcontroller's software.

3. Outcomes:

- An integrated system that provides an automated solution to the current mechanical design of the balance of the wind tunnel used at the University of Puerto Rico, Mayaguez.
- A robust system ~~that is~~ designed specifically to adjust to the design of the wind tunnel ~~of the facility~~. ~~By adjusting, the system will be able to compensate for errors presented in measurements.~~
- A robust interface that maintains version control and storage of the data generated by the experiments conducted in the tunnel.

4. Methodology and Metrics

A high level diagram of the system can be seen in figure 1:

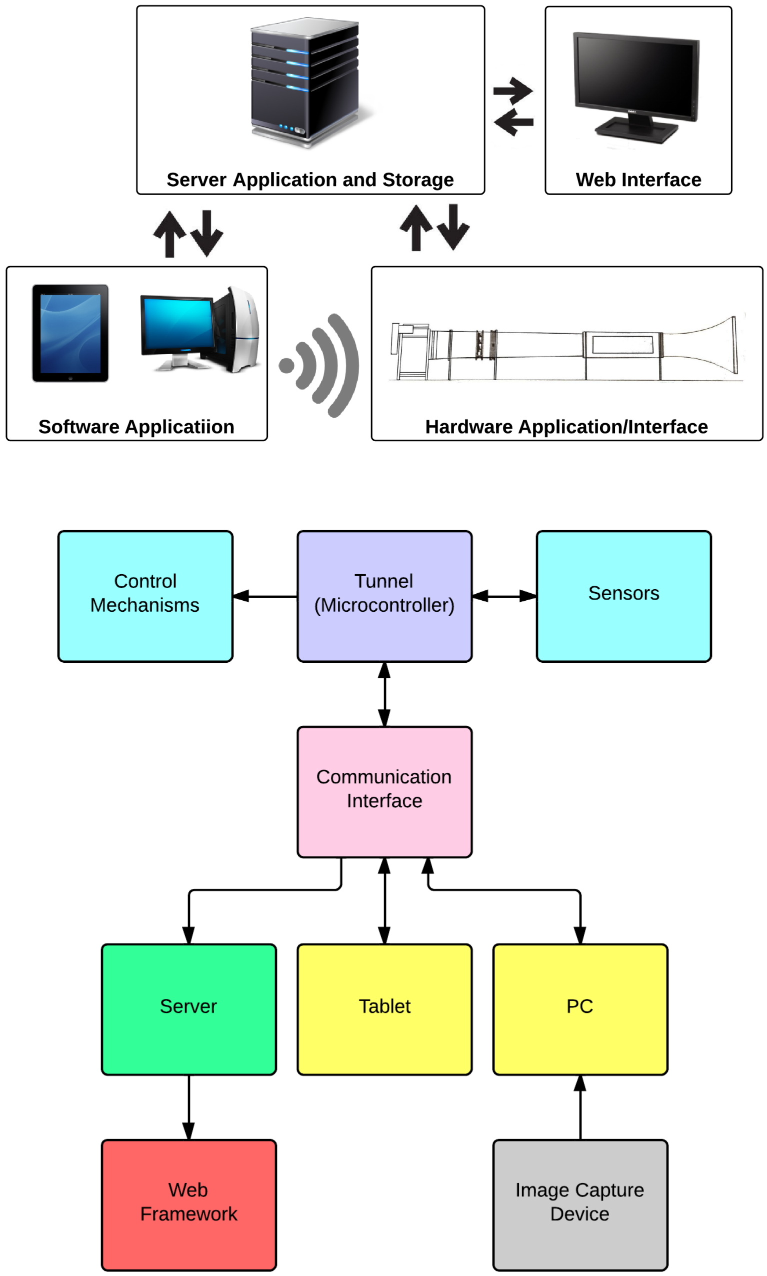


Figure 1. High Level Diagram

The team will be divided into two groups: the hardware team and the software team. The hardware team will be responsible for installing the system in the facility, developing the new hardware components, and the software team will be primarily responsible for developing the software application both in tablet and PC and a server side with a web framework that allows future processing of historical data. Both teams will work in the communications module of both sides.

The project at hand is based on the integration of modules which contain the new features. Therefore the metrics used to track progress will be based on the completion of the tasks which can also be divided in the same manner:

Hardware team:

- Design and implement window motor control hardware.
- Implement wind speed control system (algorithm)
- Implement a communication interface between microcontroller and server.
- Perform Signal Conditioning on strain gauge signals.
- Design and Implement PCB.
- Design balance base and install it along with balance.
- Implement an extra sensor for side force measurement and a tunnel external barometric pressure sensor for additional wind speed corroboration.
- Install cabling, sensors and encasing for circuitry.
- Install Power Supply in implementation.
- Refine previous microcontroller's software.
- Implement software library for added components.

Software team:

- Web Server
    - Database Design and Implementation for Data Storage
    - Web Server Dashboard for Historical Data
    - Statistical Analysis Capability
    - REST API to access data.
    - Coefficient Calculation (Aerodynamics related).

    - Historical Collection of Experiments
- PC application.
    - Implement tablet features into PC
    - Wind Speed Calculations
    - Statistical Visualization of experimental data
    - Access Control Privileges
    - Image Capture of Models to store on Database
    - Database Storage
- Tablet Application
    - Basic Experiment Management
    - Statistical Visualization of experimental data
    - Alternate method to capture Images

5. Team Organization

The team's development strategy is ~~composed of~~ the Scrum Framework. This framework divides work by sprints (time intervals) with goals to be completed. Sprints will be set at 1 week each with a series of meetings specified for each. They are the following:

- Sprint Planning: First meeting to plan out objectives for the sprint.
- Daily Sprint: Short meeting everyday, to update the entire team.
- Sprint Review: Last meeting to inspect, review and update the product increment.

6. Budget and Financial Aspects

The project is sponsor by Dr. Raul Zapata and the UPRM Civil Engineering Department. Since the project is an extension of a previous implementation, most of the expenses are already covered. Since the aim includes a full deliverable product, new locations cost are included. These are installation base, wiring, tablet and a new computer station for the final deliverable in the Civil Engineering Building.

7. Project Schedule

The project is scheduled to begin development on the 4th of February 2014, and end on May 5th. This allow for a total of 13 weeks of development for the project. A Gantt Chart was developed and is detailed in Appendix #A.3.

8.References

[1] Departamento de Ingeniería Civil y Agrimensura, (2013) Laboratorio de Tunel de Viento, [Online], http://ingenieria.uprm.edu/inci/mod/page/view.php?id=33

[2] A. Llanos, J. Luzon, J. Lebron, J. Mendez. AeroBal Blog, 2 Sept. 2013. Web. 24 Jan. 2014. ‹http://aerobalmicro2.blogspot.com/›.

[3] K. Schwaber, J. Sutherland (2013), The Definitive Guide to Scrum: The Rules of the Game [Online], https://www.scrum.org/Portals/0/Documents/Scrum%20Guides/2013/Scrum-Guide.pdf

9. Appendix

A.1 Market Overview

The proposed system is designed to enhance balancing systems used in wind tunnels, and thus has a targeted market of organizations or individuals who want to enhance the precision ~~O~~r data collection on their wind tunnels. There is currently no general commercial solution for a self built wind tunnel like this. Since wind tunnels are built in various ways with different sizes and power outputs, the systems used for measurements can be distinct and in turn are developed by the makers of the wind tunnel itself. Commercial wind tunnel vendors may include their own version for their wind tunnels, which may not be adaptable, or cost efficient for self-made wind tunnels. This makes our project useful for any wind tunnel that uses a similar rod balancing system for measurements on the object inside, which would enhance precision and the speed of data collection.

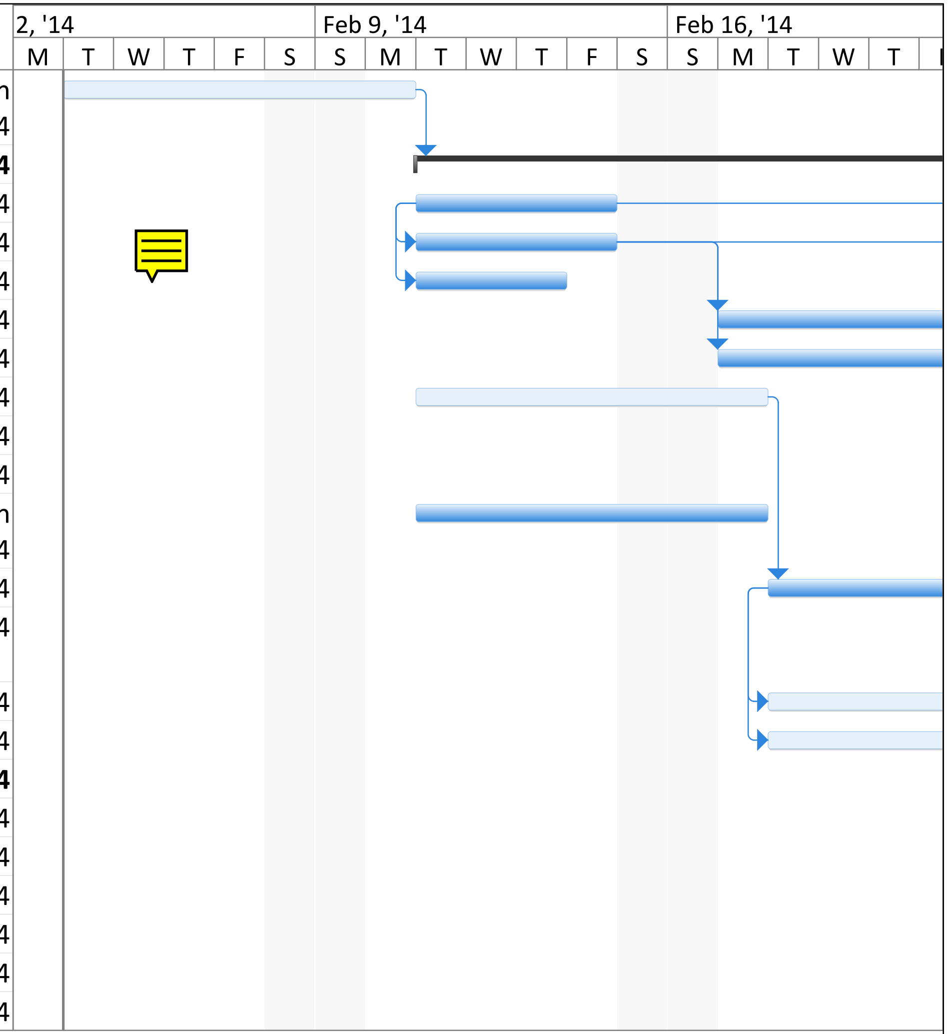
A.2 Risk Management

Risk	Probability	Impact	Actions
Loss of Data	Low	Low	Repository will be backed up externally. Project will continue from last available backup.
Damages to Engineer's Workstation	Low	Low	Workstations provided on campus will be used as a replacement. Engineer's workstations.
Server Functions Suspended or Halted	Low	Medium	Server will be simulated on local workstations if feasible or service will be rented until server is repaired.

Natural Disaster	Low	High	If wind tunnel is affected, project will be continued in prototype box until wind tunnel is usable again.
Team Member Becomes Sick	Low	Medium	If any member is rendered unable to fulfill their duties, their tasks will be delegated accordingly to maintain sprint punctuality.
Team Member Withdraws From Course	Low	High	Team members have agreed to continue working on the project after withdrawal. If member is unwilling or unable, delegation must occur accordingly.
Hardware Components are Late or Faulty	Medium	Medium	Budget allows for overnight shipping of parts in emergency cases.

A.3 Gantt Chart

ID		Task Name	Duration	Start	Finish
1		Detailed System Specification	1 wk	Tue 2/4/14	Mon 2/10/14
2		**System Design**	**19 days**	**Tue 2/11/14**	**Fri 3/7/14**
3		Communication Protocol	4 days	Tue 2/11/14	Fri 2/14/14
4		Communication API	4 days	Tue 2/11/14	Fri 2/14/14
5		PCB Design	3 days	Tue 2/11/14	Thu 2/13/14
6		Image Capture Device	2 wks	Mon 2/17/14	Fri 2/28/14
7		Signal Conditioning Module	1 wk	Mon 2/17/14	Fri 2/21/14
8		PC Application	1 wk	Tue 2/11/14	Mon 2/17/14
9		Motor Control Circuit	5 days	Mon 2/24/14	Fri 2/28/14
10		Motor Control Algorithm	1 wk	Mon 3/3/14	Fri 3/7/14
11		System Architecture and Interface	1 wk	Tue 2/11/14	Mon 2/17/14
12		Tablet Application	1 wk	Tue 2/18/14	Mon 2/24/14
13		Server Architecture and Communication	1 wk	Tue 2/25/14	Mon 3/3/14
14		Database Planning & Design	1 wk	Tue 2/18/14	Mon 2/24/14
15		Web Application	1 wk	Tue 2/18/14	Mon 2/24/14
16		**Implementation**	**20 days**	**Tue 2/25/14**	**Mon 3/24/14**
17		Communication Modules	4 days	Tue 2/25/14	Fri 2/28/14
18		Signal Conditioning Module	4 days	Tue 2/25/14	Fri 2/28/14
19		PCB Integration	2 days	Tue 2/25/14	Wed 2/26/14
20		Motor Modules	3 days	Thu 2/27/14	Mon 3/3/14
21		Server Modules	1 wk	Tue 2/25/14	Mon 3/3/14
22		PC App and Tablet App	10 days	Tue 3/4/14	Mon 3/17/14



Project: List of tasks
Date: Fri 1/24/14

Task
Split
Milestone
Summary
Project Summary
External Tasks
External Milestone
Inactive Task
Inactive Milestone
Inactive Summary
Manual Task
Duration-only
Manual Summary Rollup
Manual Summary
Start-only
Finish-only
Deadline
Progress
Manual Progress

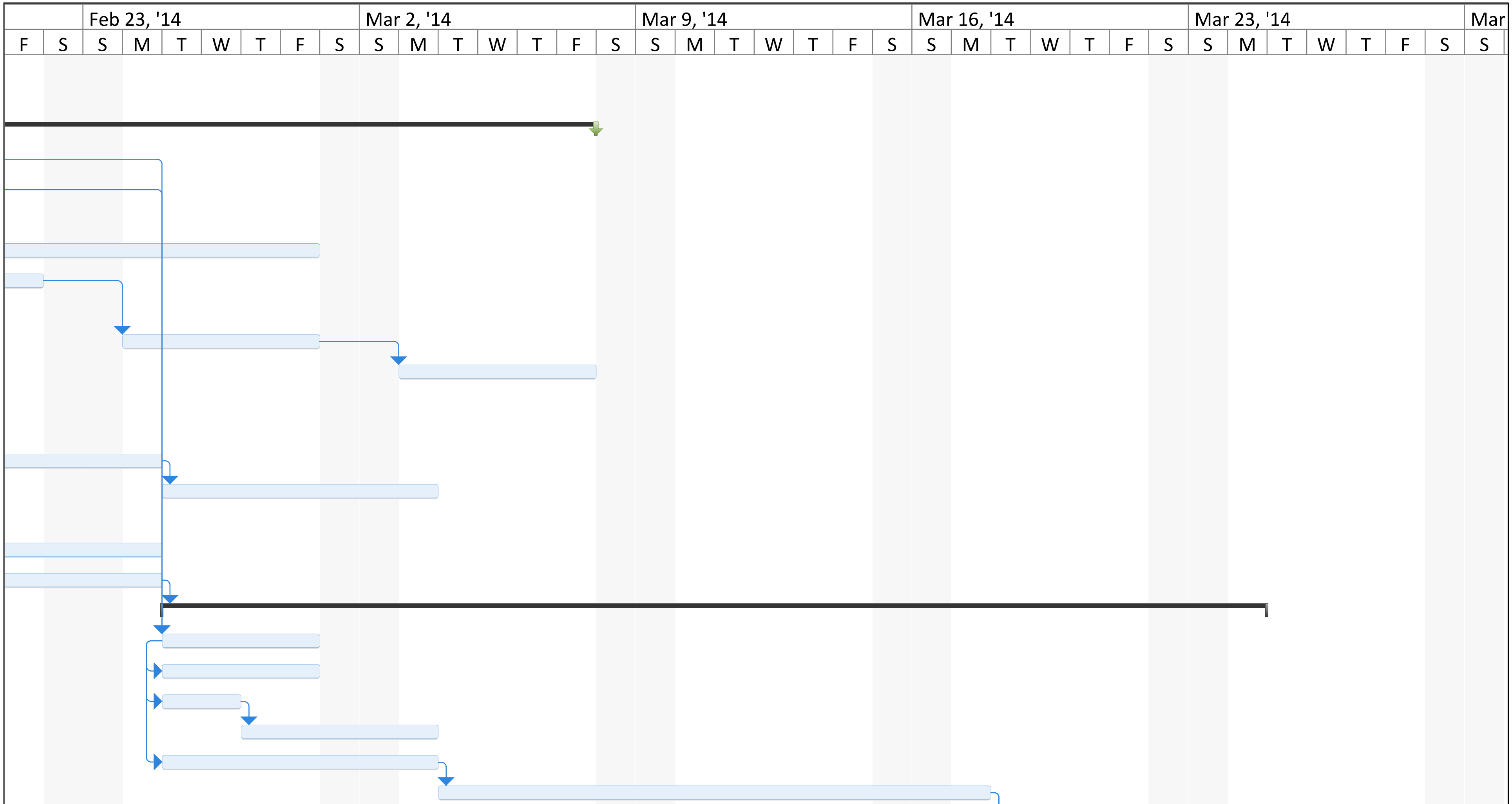
ID		Task Name	Duration	Start	Finish
23		Image Capture Device	1 wk	Tue 3/18/14	Mon 3/24/14
24		**Unit Testing**	**6 days**	**Tue 3/18/14**	**Tue 3/25/14**
25		Communication Modules	3 days	Tue 3/18/14	Thu 3/20/14
26		Signal Conditioning Module	3 days	Fri 3/21/14	Tue 3/25/14
27		Motor Modules	3 days	Fri 3/21/14	Tue 3/25/14
28		Server Modules	3 days	Tue 3/18/14	Thu 3/20/14
29		PC App and Tablet App	3 days	Fri 3/21/14	Tue 3/25/14
30		Image Capture Device	3 days	Fri 3/21/14	Tue 3/25/14
31		**System Integration**	**21 days**	**Wed 3/26/14**	**Wed 4/23/14**
32		HW Interface and Signal Conditioning Module	3 days	Wed 3/26/14	Fri 3/28/14
33		HW Interface and Motors Modules	3 days	Mon 3/31/14	Wed 4/2/14
34		HW interface & PC Application	2 days	Thu 4/3/14	Fri 4/4/14
35		HW Interface & Tablet Application	2 days	Mon 4/7/14	Tue 4/8/14
36		Tablet Application And Server	5 days	Wed 4/9/14	Tue 4/15/14
37		PC Application & Server	5 days	Wed 4/16/14	Tue 4/22/14
38		Image Capture Device and PC	5 days	Wed 4/9/14	Tue 4/15/14
39		System Demo	3 days	Wed 4/16/14	Fri 4/18/14
40		Full integration	1 day	Wed 4/23/14	Wed 4/23/14
41		**Delivery**	**8 days**	**Thu 4/24/14**	**Mon 5/5/14**
42		Deployment on site	3 days	Thu 4/24/14	Mon 4/28/14
43		Training	4 days	Tue 4/29/14	Fri 5/2/14
44		Client acceptance	1 day	Mon 5/5/14	Mon 5/5/14

2, '14 | Feb 9, '14 | Feb 16, '14

M T W T F S S M T W T F S S M T W T

Project: List of tasks
Date: Fri 1/24/14

Task	Inactive Task	Start-only
Split	Inactive Milestone	Finish-only
Milestone	Inactive Summary	Deadline
Summary	Manual Task	Progress
Project Summary	Duration-only	Manual Progress
External Tasks	Manual Summary Rollup	
External Milestone	Manual Summary	



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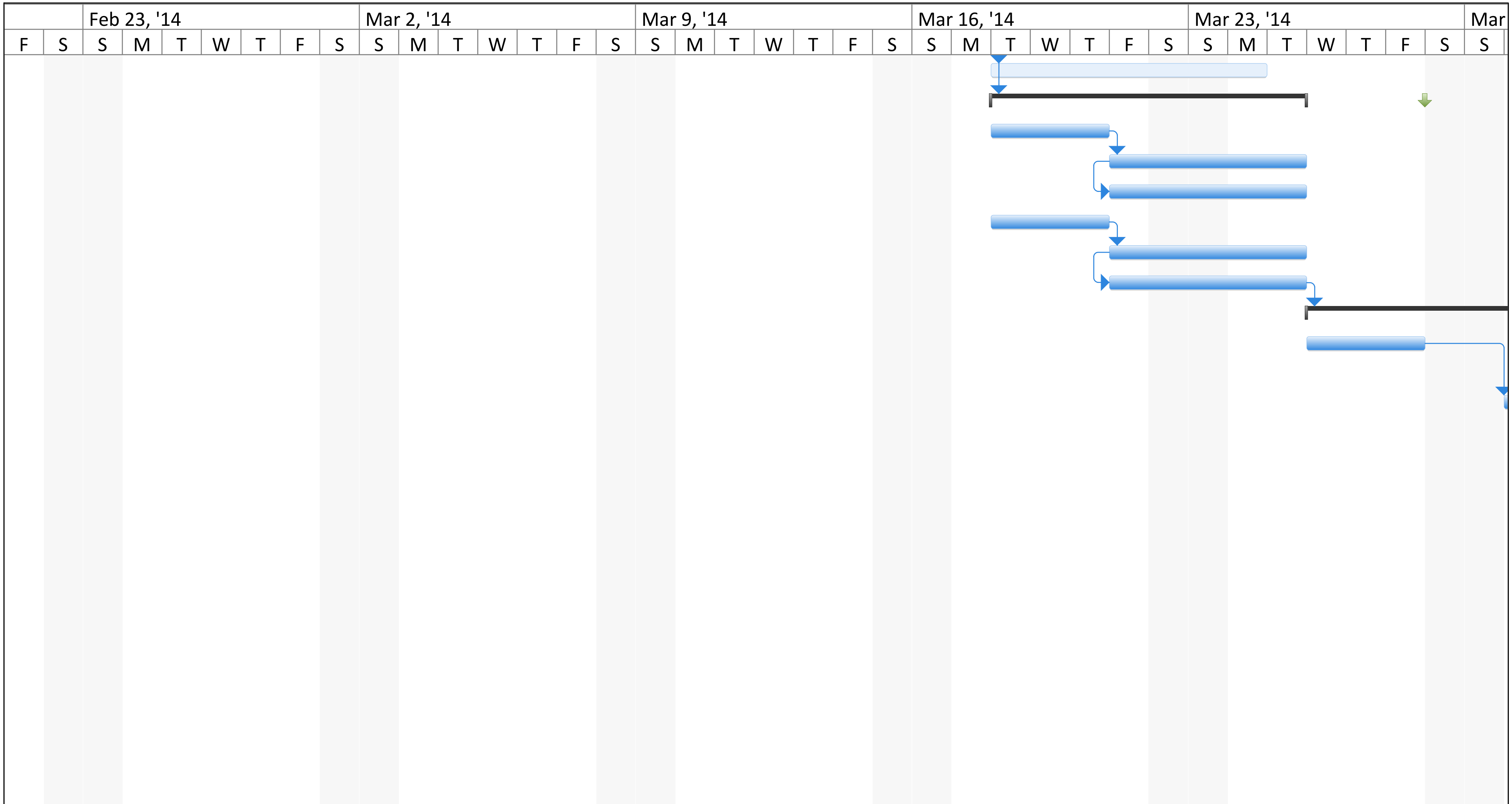

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Date: Fri 1/24/14

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Split	Inactive Milestone	Finish-only
Milestone	Inactive Summary	Deadline
Summary	Manual Task	Progress
Project Summary	Duration-only	Manual Progress
External Tasks	Manual Summary Rollup	
External Milestone	Manual Summary	

30, '14						Apr 6, '14							Apr 13, '14							Apr 20, '14							Apr 27, '14							May 4, '14			
M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W

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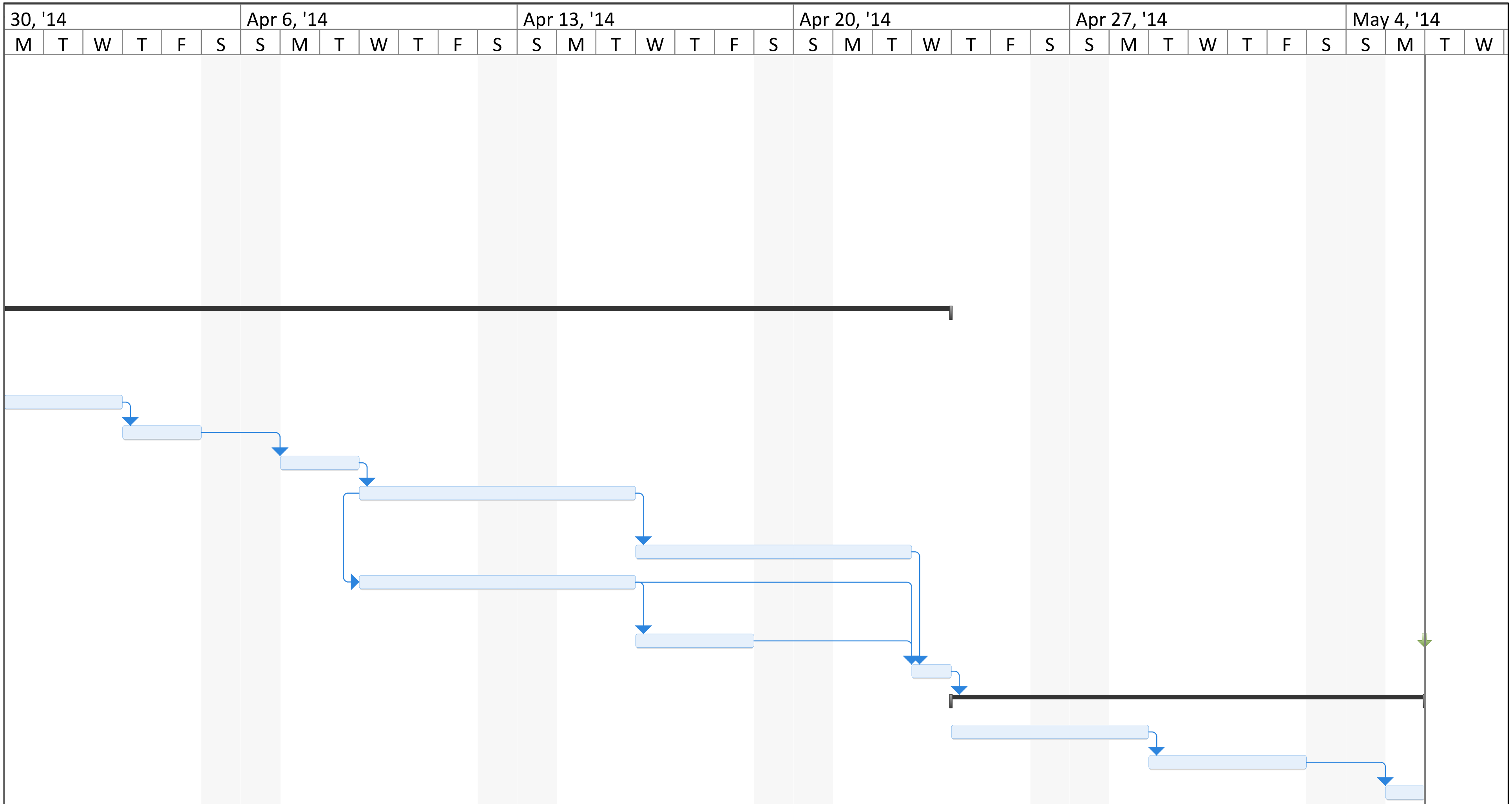

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