Managing Design and Development of Electronic Embedded System Projects

Sanjivani Balkrishna Khatavkar¹, Dr. B.E. Narkhede², Prof. M.R. Shirole³

¹,²,³M. Tech(Project Management), Department of Production Engineering, Department of Computer Science and Engineering, Veermata Jijabai Technological Institute, Mumbai, INDIA

ABSTRACT

Embedded systems and software are driving the new-age lifestyle, encompassing various aspects of modern life. As hardware becomes powerful and cost effective, embedded software in devices expands its footprint in various areas such as consumer electronics, transportation, medicine, and manufacturing.

Due to the complex system context of embedded-software applications, defects can cause life-threatening situations, delays can create huge costs, and insufficient productivity can impact entire economies. Providing better estimates, setting objectives, and identifying critical hot spots in embedded-software engineering requires adequate benchmarking data.

The goal is to define a model using which the design and development of electronic embedded system projects can be managed effectively. This enables the project team to systematically and effectively identify, track and ultimately realize project goals. To optimize timelines, productivity and quality of embedded system development, industry needs process techniques and project management methods that are able to effectively tackle specific situations.

Keywords---- Embedded project management, Embedded product development, Goal Driven Approach, Model Driven Development

I. INTRODUCTION

Our lives are surrounded by overwhelming number and variety of information equipment. Many of them provide their required functionalities by systems called embedded systems. Embedded systems are designed to perform a dedicated function and often integrated with mechanical machines.
• Real time operating systems (RTOS) - including board support package and device drivers
• Industry specific protocols and interfaces
• Printed circuit board assembly

Usually, an embedded system requires mechanical assembly to accommodate all of the above components and create a product or complete embedded device.

Therefore, embedded systems invariably have limited resources available in terms of memory, CPU, screen size, a limited set (or absence) of key inputs- these parameters play a crucial part during the design, development and testing of such systems. As organizations are under immense pressure to achieve higher levels of device integration while reducing cost, size, and complexity, the issue of process innovation has become very significant.

A survey released at the Embedded Systems Conference (ESC 2006) indicated that more than 50% of embedded design projects are running behind schedule (i.e., 25% are 1-2 months late, 18% 3-6 months). In the 2008 version of the survey, it is again shown that, meeting the schedule is the greatest concern for design teams.

Compared to regular software development, embedded system development appears more complex and difficult due to inherent constraints within the embedded system as well as other systems outside but in environment of the embedded systems.

This paper reports experiences and lessons learned by applying Goal Driven method in a small scale company in Mumbai whose main business area is vision systems and embedded system development. Several projects adopted Goal Driven method. And here, one project was selected as focused project. The project included both hardware and software development. In the study, we explored initiative to adopt goal driven method as a project management method and evaluated the impact of the method during the project.

The paper is structured as follows. Section 1 provides the background and the purpose of the paper along with literature review. Section 2 gives a brief introduction to Goal driven method. Section 3 describes the context of case study. Section 4 elaborates the implementation details of the case study. Section 5 describes the learning and limitations of the case study.

II. BACKGROUND AND PURPOSE

Today’s products may have many advanced features enabled through the use of software driven electronics. Automobiles have advanced safety features and automatic controls. Home appliances have software powered controls designed to provide automated features and energy saving controls. In order to compete, manufacturers need to be able to synchronize all aspect of complex product and process design. They must optimize product performance, integration and quality by unifying mechanical, electrical and software subsystems- many of which may be designed by supplier.

Developing these embedded system products involves a set of challenges in coordinating different engineering disciplines on a single design. Some of these challenges are given below[12]:

**Heterogeneity:** In electronic embedded system projects multiple style algorithms using different technologies.

**Reliability expectations:** An electronic embedded system must eliminate bugs present if any. Also, memory management is a critical issue in the embedded projects like memory leak or stack overflow.

**Complexity:** In an embedded project, more and more functionality is developed onto a single system. The system has to be interfaced with various subsystems with real time requirements. Hence they are more complex.

**Requirement management:** The requirements in an electronic embedded system projects continuously change, updated, deleted or created new ones.

All of the above, results in products with complex multidisciplinary design, increased product data and information to be managed and shared in organization. Hence organizations are in a need for a system that can address the rising complexity of products, need to collaborate with real time data, manage product information from centralized location.

Thus the purpose of this paper is to define a model using which the design and development of electronic embedded systems can be managed effectively. This enables the project team to systematically and effectively identify, track and realize project goals. To optimize productivity and quality of embedded system projects, one needs to adopt project management techniques to effectively tackle the specific situations.

III. LITERATURE REVIEW

For the project topic Managing design and development of embedded system projects the study is carried out. The literature studied is some books and some research papers which deals with embedded systems and challenges in managing their development. Some research papers have given an approach to develop an embedded system project to avoid delay and excessive cost.

The available models for the development of the systems are studied and comparison is carried out. [Pressman]. The comparison can be stated as in the table below.

<table>
<thead>
<tr>
<th>Features</th>
<th>Waterfall</th>
<th>Iterative</th>
<th>Spiral Model</th>
<th>V-shaped</th>
<th>Big Bang</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirement Specific</td>
<td>Beginning</td>
<td>Beginning</td>
<td>Beginning</td>
<td>Beginning</td>
<td>Frequent Changed</td>
</tr>
<tr>
<td>Requirement</td>
<td>Well Understood</td>
<td>Not Well Understood</td>
<td>Well Understood</td>
<td>Not Well Understood</td>
<td></td>
</tr>
<tr>
<td>-----------------------------------------</td>
<td>-----------------</td>
<td>---------------------</td>
<td>-----------------</td>
<td>---------------------</td>
<td></td>
</tr>
<tr>
<td>Understanding Requirements</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost</td>
<td>Low</td>
<td>Low</td>
<td>Expensive</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>Availability of reusable component</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Complexity of system</td>
<td>Simple</td>
<td>Simple</td>
<td>Complex</td>
<td>Simple</td>
<td></td>
</tr>
<tr>
<td>Risk Analysis</td>
<td>Only at beginning</td>
<td>Less Risk Analysis</td>
<td>Yes</td>
<td>Less Risk Analysis</td>
<td></td>
</tr>
<tr>
<td>User Involvement in all phases of SDLC</td>
<td>At beginning</td>
<td>Intermediate</td>
<td>High</td>
<td>At beginning</td>
<td></td>
</tr>
<tr>
<td>Overlapping Phases</td>
<td>No overlapping</td>
<td>No overlapping</td>
<td>Yes overlapping</td>
<td>No overlapping</td>
<td></td>
</tr>
<tr>
<td>Implementation time</td>
<td>Long</td>
<td>Less</td>
<td>Depends on project</td>
<td>Long</td>
<td></td>
</tr>
<tr>
<td>Flexibility</td>
<td>Rigid</td>
<td>Less Flexible</td>
<td>Flexible</td>
<td>Less Flexible</td>
<td></td>
</tr>
<tr>
<td>Changes Incorporated</td>
<td>Difficult</td>
<td>Easy</td>
<td>Easy</td>
<td>Easy</td>
<td></td>
</tr>
<tr>
<td>Expertise Required</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td></td>
</tr>
</tbody>
</table>

The main limitation of all these models is they consider only software development part. But an embedded system consists of hardware also, so one has to manage both. Hardware part of an embedded system projects might need more monitoring and controlling so as to complete the project within its constraints.

Embedded systems have to rely on high quality hardware as well as high quality software. But as the complexity and diversity of application increases, a number of embedded projects are struggling to deliver a quality product within budget and on time. The embedded market survey indicates top three concerns are related to project management aspects during electronic embedded system development. Those three concerns are: meeting schedules, increased lines and complexity of code, sticking to cost budget.

As stated earlier, an electronic embedded system has hardware and software functionality. The biggest challenge is to integrate both in an effective manner. Software people must understand the nature of hardware design and types of problems faced by hardware team. They also must understand the possibilities and capabilities of hardware. Likewise hardware team must have understanding of software and how application operates.

Thus the purpose of this paper is to define a model using which the design and development of electronic embedded systems can be managed effectively. This enables the project team to systematically and effectively identify, track and realize project goals. To optimize productivity and quality of embedded system projects, one needs to adopt project management techniques to effectively tackle the specific situations.

**IV. INTRODUCTION TO GOAL DRIVEN METHOD**

A goal is defined as an explicit or implicit expectation from relevant stakeholders of a certain project. These relevant stakeholders who are involved in a project typically include customers, end users, management and developers.

For example, a response time less than 2 seconds is a performance goal, while a balance between job time and family time is team member’s personal goal. The former goal maybe the expectation of customers or management, which will be taken as requirement. The latter is the expectation of project team which will not be taken as requirement.

The goal driven model has three sections. Namely;

A. Process framework and profile chart
B. Incremental hardware estimation
C. Risk identification

**A. Process framework and profile chart**

The process framework consists of three primary phases. Each phase has number of activities to be carried out. The output of each phase helps in managing the embedded project.
1. Define phase

1) Goal definition: define the expectations of stakeholders as goals of the project. The goals may be internal (expectations of the team members and developers) or external (expectations of customers and management). A tree diagram (mind map) of goals is drawn for better understanding.

2) Goal analysis: This step analyses all the goals on leaves to identify any potential conflicts and duplication among goals. This step refines the tree structure.

3) Goals allocation: This step allocates all the goals on leaves among team members according to preference and balanced workload. Normally each goal is assigned an owner, who is responsible to develop implementation solution, and track the progress during the implementation.

4) Goals implementation solution: the owner of the goal is responsible for developing solutions for implementation of goal. The owner must keep in mind the constraints if any while developing solutions. Document the solutions and constraints for each goal.

2. Develop phase

1) Goals implementation: The actual implementation starts using the implementation solutions defined in define phase. The owner of each goal practices the solution and achieves goal.

2) Goal tracking and status reporting: This practice tracks and reports the status of all the goals identified.

Profile chart: The owner of goal collects the data and evidences and reports to team leader who puts all goals’ status into a single chart called profile chart.

Profile chart gives the indication of status of completion of goal using graphical representation (Bar chart). This helps in tracking the project success.

Graphical representation makes it easy to keep track of project’s goals.

3. Explore phase:

This phase gives the experiences and learning during the period of project completion (meeting the goals). In this phase answers for two questions are obtained.

1) How did all the goals support expectation of all the stakeholders?

2) How did all implementation solutions help to achieve goals?

Thus this section gives us identified goals, their implementation solutions and status tracking of those goals. This framework is backbone of our proposed model.

In the goals one goal is achieving project schedule that means developing a project in a scheduled time period. For efficient schedule management, time estimation should be done with higher accuracy. The time estimation of software projects has different approaches and most of them are efficient. But an electronic embedded system has software as well as hardware part also, so hardware estimation is essential requirement in the embedded project management.

A. Incremental hardware estimation:

Our proposed Goal driven model uses a method for estimating the time. This method is known as incremental hardware estimation.

This is a bottom up approach of estimation. In this method the goals are divided into different hardware functions. These hardware functions are further divided into sub functions. Each sub function is again divided into states. Now, states are the parts which can be assigned a time period. By adding these time periods, a time for each sub function is obtained. And by adding time for each sub function, a time for the hardware function is obtained. Finally summation of all hardware functions’ time periods gives us a final schedule. Thus, the name is given to this method is incremental hardware method.

Now, the time period assignment of states is done using parametric estimation technique. In this parametric estimation technique, the time estimated depending upon some defined parameter.

The two parameters considered the most are:

i) functional complexity of the state

ii) Number of components in the state

Depending upon a selected parameter, with the help of historical data and expert knowledge, the time periods are assigned. This method is near to accurate and efficient.

B. Risk identification:

Risk is the possible undesirable outcome or a loss. Risk impact is defined as the probability of loss multiplied by the cost of loss. Risk management is a discipline which identifies analyses and eliminates the risk events before they become either threats to the successful operation of project or cause project rework.
The two main steps in risk management are risk assessment and risk control. The sub steps in risk assessment are risk identification and risk prioritization whereas risk control has risk management planning and risk monitoring.

Risk identification produces a list of risk events possible in the given electronic embedded project. This risk identification is done in parallel with the define phase of the process framework. The techniques of risk identification are:

1) Historical data: refer to the documented data you already have of similar kind of project.
2) Brainstorming: brainstorm among the project team members
3) Assumptions and constraints: the project’s assumptions and constraints also lead to risk events.

Performing inspections is a method of reducing risks. By reviewing the outcomes of one phase before they are used in subsequent phases, defects are found and eliminated beforehand.

IV. INTRODUCTION TO CASE STUDY

In any organization be that an industry or an educational institute, clocks are used everywhere. Presently, the clocks used do run on battery and are controlled manually. In large industries for entering incoming and outgoing time of an employee there is either smart card system or biometric system. But in small or medium scale industries they rely on entering manually on a muster. This reflects on productivity if clocks do not show same timings. As well as in the production plants, the clock time must be same as clock in administrative office. The battery replacement time should be avoided i.e. the clocks with digital display running on the mains power supply. Keeping in mind these requirements, a product is designed named, real time clock (RTC). The product design and development is carried out in the Industry as per the proposed model i.e. Goal Driven model.

The real time clock high level specifications are as follows:

- One master clock with red colour seven segment display(4 inch)
- Four slave clocks with red colour seven segment displays(4 inch)
- Wireless connectivity between master and slaves(wifi)
- Wired connectivity between master and slaves(RS 485)
- Power supply for each clock unit (5V DC)
- GPS unit interfaced with master clock

Implementation of process model

The case study is implemented using the defined model as shown here:
1. Define goals:

![Tree structure of goals diagram]

2. Time estimation:

Method: Incremental Hardware Estimation

Parametric estimation technique:

<table>
<thead>
<tr>
<th>Complexity of state</th>
<th>Low</th>
<th>Medium</th>
<th>Critical</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1 day)</td>
<td>(3 days)</td>
<td>(5 days)</td>
</tr>
</tbody>
</table>

In this embedded project, there is one master and four slaves. These hardware functions are divided into sub functions and further into states. And depending on parametric estimation time is assigned to each of them.
Figure 3: Estimation for Master unit

- GPS connectivity
  - Interfacing & programming GPS with controller
    - Critical 5 days

- Display 7 segment LED
  - Designing 7 segment & interfacing using decoder
    - Medium 3 days

- Communication
  - Interface & program RS 485 and WiFi
    - Critical 5 days

- Power Supply
  - Transformers, Filters, Regulators circuit
    - Low 1 day

Figure 4: Estimation for Slave unit

- Slave

- Communication
  - Interface & program RS 485 and WiFi
    - Critical 5 days

- Display 7 segment LED
  - Designing 7 segment & interfacing using decoder
    - Medium 3 days

- Power Supply
  - Transformers, Filters, Regulators circuit
    - Low 1 day
Hence, the total estimated time to complete the project is the summation of all these assigned time values.

Thus,

Total estimated time = 5+3+5+1+5+3+1

= 23 days

Thus, the project must be completed within 23 working days. This is the schedule plan. The start date of the project is 1st September 2014. Hence, the project must be completed on 25th September 2014. The progress is tracked through this project.

3. The profile chart:

This is used to track project progress. One example is shown here. The project progress on 16th September is shown below.

Thus according to the progress chart, the further planning is made and actions are taken. The graphical presentation makes it easy to track the status of goals.

Team leader takes daily meetings to track the progress of the project.

In case of RTC, the project got completed on the scheduled date i.e. on 25th September 2014. Hence, it is a successful model to track the project and manage it.

4. Experiences and learning:

The implementation of the project solutions is done according to specifications and resources did stick to the project schedule.

Some goals lag behind the schedule, but at the end they are completed in time. The critical functions like GPS and communication functions did take some extra time. But finally, the team managed to complete the project within time.

V. CONCLUSION

The electronic embedded project Real Time Clock, is scheduled to complete in 23 days. The implementation is designed according to Goal Driven model. In GD model hardware and software modules are designed and implemented concurrently. This method has proven very efficient in completing the project as per the scheduled time. The profile chart proven as easy and effective method to track progress of project.

Thus, the successful implementation of GD method gives the model to manage electronic embedded system projects. This method is efficient to manage these projects. By using this model we assure the success of project. The specifications are met, goals are achieved and time is met.

Hence the Goal Driven model is used as model to design and manage the electronic embedded projects.

REFERENCES

[5] Risk areas in embedded software industry
[8] Sukirti Jalal, “Trends and Implications in Embedded system development” Markus Hermannsdörfer and Thomas
[10] Nuno Silva and Rai Loper, “Planning and building Qualifiable embedded systems”