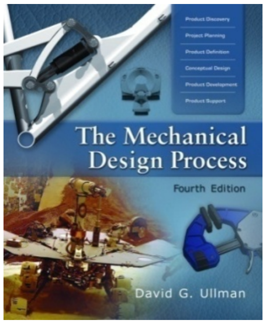
Spiral Product Development at Syncromatics



A Case Study for *The Mechanical Design Process*

Introduction

This case study focuses on the development of Solar Powered Shelter Signs by Syncromatics Corp. Syncromatics is a provider of Intelligent Transit Systems (ITS), specializing in bus tracking, automated passenger counting, passenger information systems and route analytics. Solar powered shelter signs are erected to communicate bus arrival times and destinations to riders waiting at a bus stop. With these signs, riders have clear information about what to expect and when.

Figure 1: The Solar Powered Shelter Sign

Syncromatics Solar-Powered Shelter Signs operate over cellular networks and require no wiring, making installation and planning of minimal effort. Further, the signs accommodate both visually and hearing impaired passengers, and are built to the specifications defined in the Americans with Disabilities Act (ADA).

One aspect of this shelter sign is that it is composed of mechanical, electronic and software components, each doing part of the sign's functions. The design process used for each of these fields is somewhat different.

In this case study:

- **The Problem**: Design a product composed of mechanical, electronic and software systems in a coordinated and timely manner.
- **The Method**: The design process is a mixture of methods where hardware and electric circuitry are fixed early and are robust enough to allow agile development of the software.
- **Advantages/disadvantages**: This method commits in sequenced fashion, mechanical, then electronic and finally software elements. This is especially advantageous as variation needs can be met by software changes that can easily and rapidly be made

The Solar Powered Shelter Sign

The solar powered shelter sign functions as shown in Figure 2. It collects power from the sun and stores it in a battery that is inside the housing. The battery is large enough and the power demands are small enough that the sign can function for 6-7 sunless days. The battery powers a cellular receiver which collects information from a system that tracks bus locations and identification. Based on this signal, the time until the bus arrives can be computed by the internal computer (IC Board) and the information displayed for the riders to see. Typical messages are of the form,"Bus 12 to Mango Heights will arrive in 4 minutes". The display is ADA (American with Disabilities Act) compliant with 3 inch characters (one line) or 2 inch characters (for two lines). For visually impaired riders there is a large button on the pole, which when pushed reads the message using an annunciator (a system that translates the text signal to spoken words).

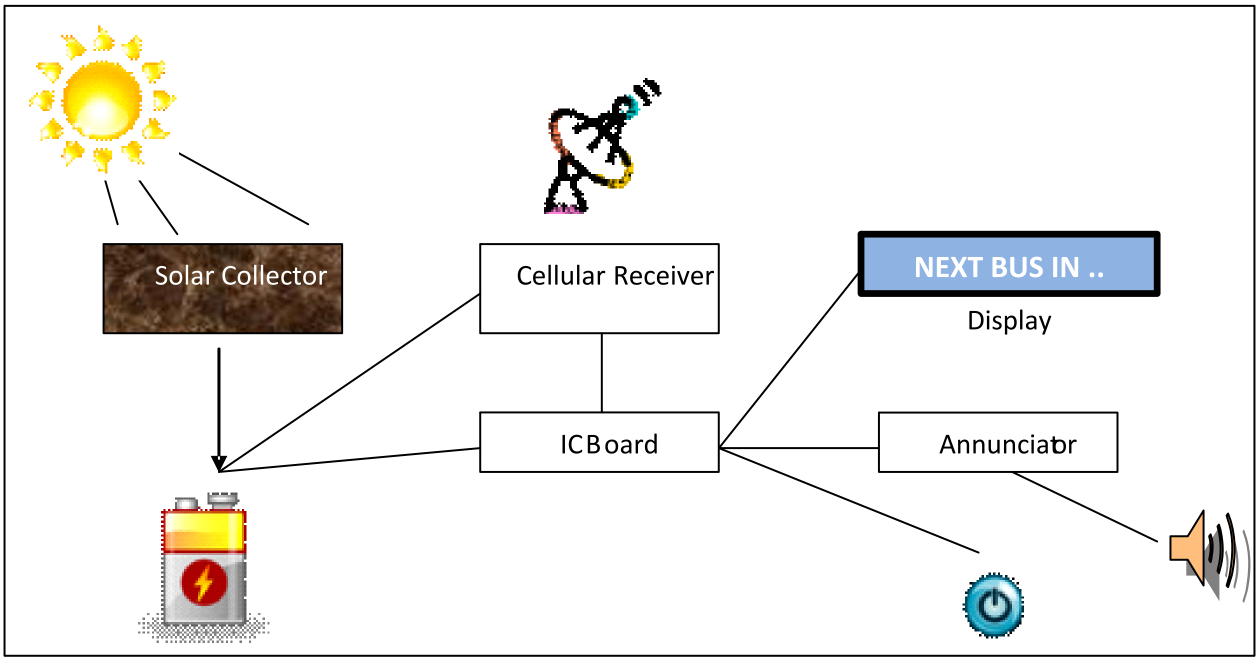


Figure 2: The system

The heart of a system like this is the software that converts a cellular signal to one that can be read and heard. The software, the display and the sound systems are all on printed battery powered circuit boards. All of the components described are connected by the physical structure. This structure must:

1. Physically support the display, PC boards, battery solar cells and cellular receiver.
2. Protect all the electronics from the weather
3. Provide channels to connect the solar panel and the button to actuate the annunciator to the other components in the main housing
4. Be tamper proof
5. Be manufacturable in small quantities.

Since this is a maturing product, and one that may need to be customized for different customers, there will be changes late in the design process and possibly once the product is in service. Thus, a further goal is to design the product so that changes can easily be made.

The Development Process

The process to develop the software, electronics and mechanical components can best be described as three separate but interdependent spirals[1]. Spiral processes have become very popular in software design and, as shown in this case study, can equally be applied to electronic and mechanical systems. Basically, spiral development begins at the center with initial requirements, shown in Figure 3. From these, some basic concepts are developed and tested with the first prototypes. These prototypes are evaluated for function and the risks identified (i.e. those problems that need to be resolved during product development). The results of this evaluation focus on the next steps, and the next loop of the spiral begins.

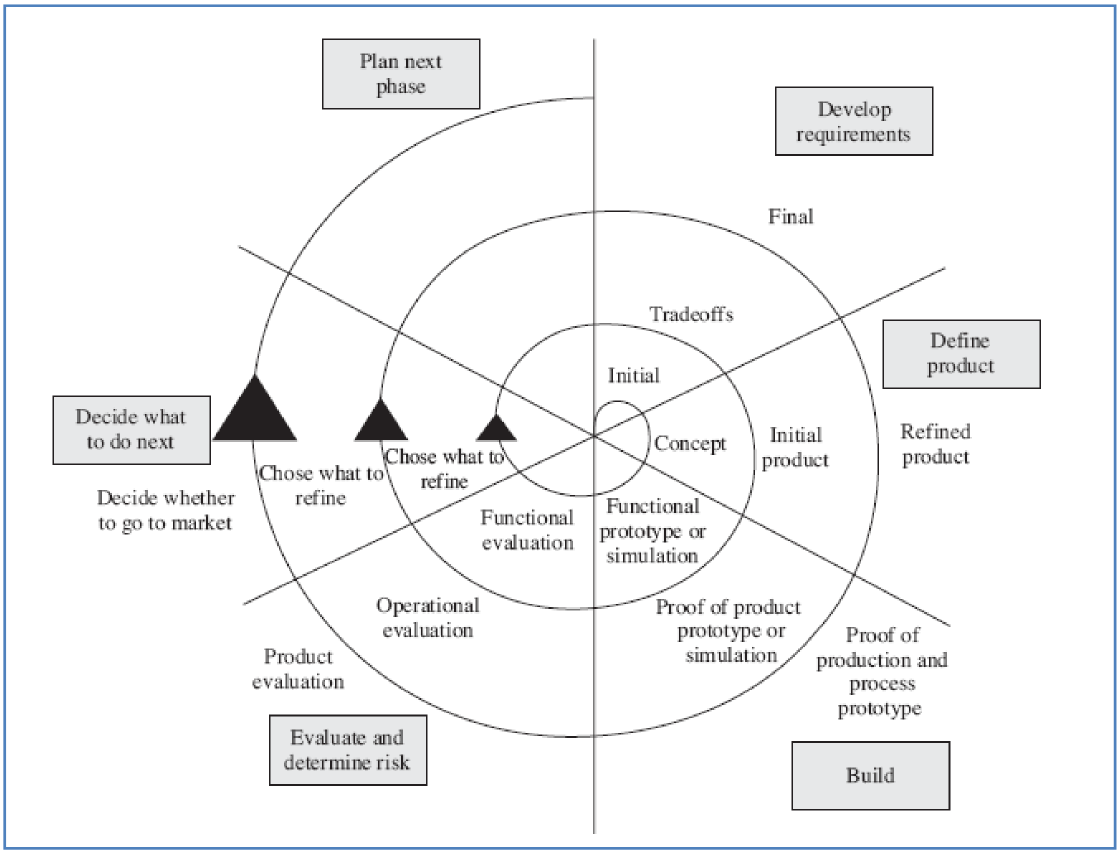


Figure 3: The spiral process (Figure 5.5 in "The Mechanical Design Process")

[1] See spiral and other processes in Chapter 5 of *The Mechanical Design Process*, 4th edition, McGraw Hill, by David G. Ullman, ISBN-13 9780072975741, www.mhhe.com/ullman4e.

In ideal practice the initial "Develop Requirements" phase would result in a complete set of specifications for the product. However, for immature products such as the Shelter Sign, this is not possible and the requirements co-evolve. Syncromatics did a careful job of the initial definition and only made changes identified in previous spirals. Concepts were developed, built and tested from these.

One importance in the spiral methodology is that each generation of prototypes moves the system closer to production. Early prototypes need to allow for quick and easy changes. It is the speed with which prototypes can be developed, tested and changed that determines how fast the product can be developed. Also, each loop is based on identified problems and refined requirements. This gives flexibility while keeping the process under control.

In the diagram, the "build" phase is characterized by the type of prototypes developed. Detailing these types can help explain the differences in the three spirals (Table 1). A key factor in this table is how long it takes to make changes. It is the changes that define each loop of the spiral and the time needed for these changes that determine how fast the design process can progress.

	Prototypes			
	Functional	Product	Process	Production
Mechanical Spiral	Inventor Drawings Changes in hours	Custom hand built Changes in weeks	Final production Changes in weeks	No changes
Electronic Spiral	Breadboard Changes in minutes	Custom PC board Changes in days	Final PC board Changes in days	No changes
Software Spiral	Code on computer Changes in minutes	Code on board Changes in minutes	Final code Changes in minutes	Change to meet customer needs

Table 1: Prototypes used in the development of the Solar Powered Sign

In the first spiral the goal was to show that the sign worked. Thus, proof-of-concept or proof-of-function prototypes were developed to demonstrate the function of the product in comparison with the customers' requirements and engineering specifications. For the mechanical system, preliminary CAD drawings were made using Autodesk Inventor, Figure 4. Changes to these solid models could be made in hours, aiding in the development to meet the structural requirements itemized earlier. Note that on previous projects, prior to using solid modeling tools, functional prototypes were made with cardboard or thin metal, and any changes took much longer.

Functional prototypes for the electronics were made on breadboards (plastic boards designed to easily mount components and run wires between them) or mocked up with off the shelf components (e.g. the cellular antenna and the display). Using a breadboard, changes could be made in minutes making concept development modifications easy to explore. Finally, software was coded into a desktop computer so that its function could be simulated and, as with most code, changes could be made in minutes.

On the second spiral, proof-of-product prototypes were developed to help refine the components and assemblies for the mechanical and electronic components. Geometry, materials, and manufacturing process are as important as function for these prototypes.

For the mechanical system, a physical prototype was hand built to match the CAD model. Once the 1st mechanical prototype was built and verified, the design was not changed. The 1st prototype ended up being the final design that went into production. Thus, the solid modeling on Inventor fulfilled both the functional and product prototype needs.

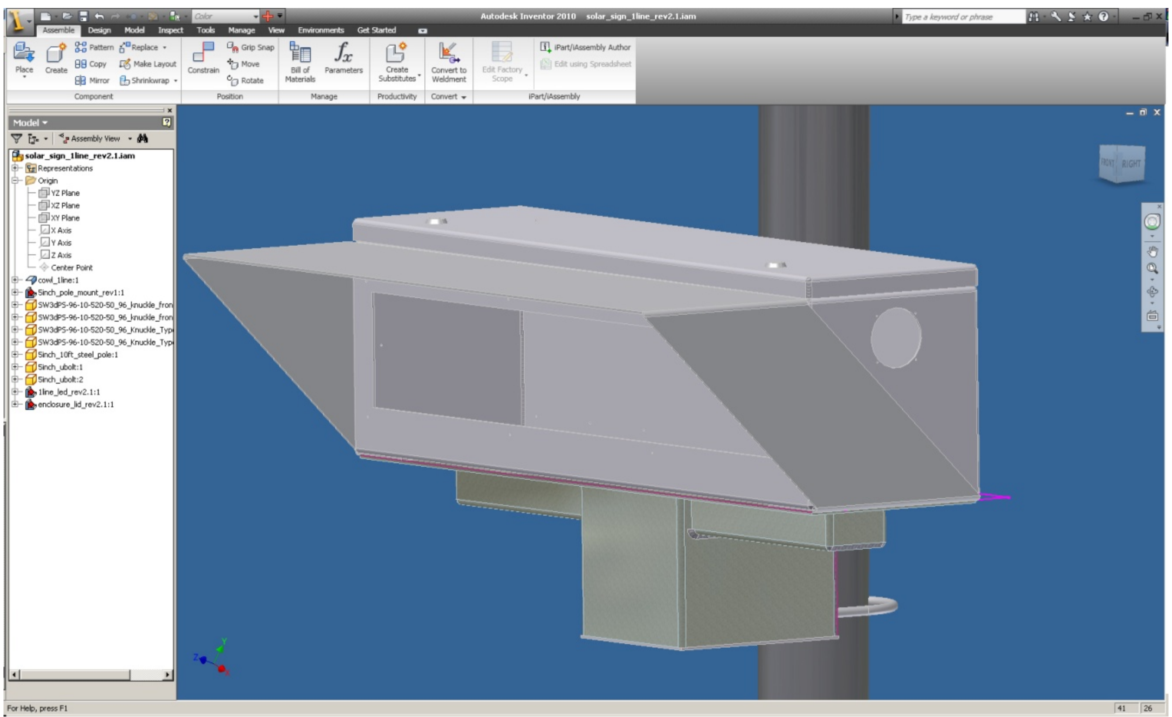


Figure 4: Early Autodesk Inventor solid model of the sign housing

Electronic PC boards were made, replacing the breadboard wiring with etched circuits. Changes could be made to these boards in hours or minutes by cutting leads on the boards and soldering in wires. However, it took days to get new boards made. As is usually the case, software changes at this stage took minutes.

The proof-of-product prototypes were installed at test customer locations to verify how they worked in real operating conditions. At this stage, much was learned about weather proofing, glare off the display and understandability of the annunciation system.

During the last design spiral, proof-of-process prototypes were used to verify the function, geometry and the manufacturing process. As noted earlier, the first physical prototype carried through to this spiral with no changes needed. Since the first prototype used the same manufacturing methods as the final product this spiral was not needed for the mechanical system. However, the next generation of the sign will use more tooling-intensive manufacturing methods such as castings and extrusions, which will result in the need for this loop in the future. As in the earlier loop, changes to the PC boards took days and changes to code minutes.

Using the spiral development process and timing the development so the three types of systems interacted at coincident times enabled Syncromatics to identify risks – potential problems - early on and make decisions that resolved them before too much commitment was made.

Syncromatics has designed the system so that any changes to the system can be made through software changes and not to the hardware and electronics, thus keeping changes quick and inexpensive.

Conclusions

Using three spirals to manage the development of the Solar Powered Shelter Signs helped Syncromatics:

- Iterate so each system could be revisited during each cycle.
- Reassess the requirements during each cycle
- Make good use of prototypes and simulations
- Enable "good enough for the moment" implementations
- Drive the level of effort by risk considerations
- Give them clear decision points in each cycle
- Each cycle provided objectives, constraints, alternatives, risks, review, and commitment to proceed.

Author

This case study was written by David G. Ullman, Emeritus Professor of Mechanical Design from Oregon State University and author of *The Mechanical Engineering Process*, 4th edition, McGraw Hill. He has been a designer of transportation and medical systems and hold five patents. More details on David can be found at www.davidullman.com. David was assisted by Stephen Salazar of Syncromatics Corp of Los Angles, California.

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