Safe at Any Speed:  
An Innovative Design Solution for Emergency Vehicles  
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Introduction

It is impossible to imagine that all manufactured products are completely safe. In addition, making products absolutely safe is not always easy. In order to protect consumers from unsafe products, federal and state law assigns specific duties to manufacturers, distributors, retailers, and service establishments [1]. Safety is the most fundamental issue that both designers and engineers must address when developing products. There are certain problems and strict regulations that are unique to the process of designing life-critical products and I contend that the best way to tackle them is through a multidisciplinary team that is able to incorporate perspectives, knowledge, and attitudes from several significant stakeholders in the design process.

In December of 2006, the Department of Industrial Design at Arizona State University in the US was contacted by a group of local entrepreneurs who proposed a collaborative project to design a safety seat product for children that would be used in emergency vehicles such as ambulances and fire trucks. The initial project parameters and time schedule provided to the faculty were brief and lacked a clear description of the details required to begin a new product development process (i.e., engineering requirements, manufacturing guidelines, business plan, etc.). The entrepreneurs were operating on a tight timeline with a goal of product launch within 6 months. In addition to the challenge of having the new product designed and manufactured within that time frame, the assembled team also had to address the missing project brief elements previously described. The schedule for the project was outlined by the faculty project leader and consequently approved by the entrepreneurs in the contract document.

The industrial design team was headed by an assistant professor with 7 years of experience in product development and expertise in assistive device design. The team also included two senior level industrial design students. The entrepreneur partners included an independent business consultant with over 15 years of executive management experience in a variety of industries, the head of Emergency Medical Equipment Research and Development for the City of Phoenix Fire Department, with over 22 years of emergency medical experience, and a captain on the Community Involvement Division of the Phoenix Fire Department with over 18 years of experience. In assembling this team, our goal was to ensure that all stakeholder needs were addressed throughout the design process, making the product manufacturable, aesthetically appealing, and ergonomically comfortable. This multidisciplinary team was able to collectively transform a simple idea into a formidable product that revolutionizes safety for children in emergency transportation.

Students brought fresh ideas and creative input, while the firefighters contributed critical knowledge about safety and regulations to this design project. In addition, the process of moving a project from preliminary ideas to finished product provided benefits to all partners—students gained valuable real world experience, the entrepreneurial firm got a close look at the inner workings of new product development, and the firefighters were able to play an active role in the design of a product that they will use.

In order to address the challenges inherent when developing products that can save people’s lives, it is wise to assemble a multidisciplinary team. The unique problems involved in designing transportation products for children required a team that was able to generate diverse perspectives and knowledge, which could then be collectively used to advance a design, informed by several significant stakeholders in the design process. Through a discussion of how this specific project progressed, I intend to illustrate valuable lessons that may be applied in other new product development contexts, particularly those that involve industry/academia partnerships and multidisciplinary teams.

The Problem and Goal
At the kick-off meeting for the project, all team members assembled at the Phoenix Fire Department. During the first meeting, the design team discussed the primary problem that the fire department had
been facing for many years: a lack of child-restraint systems within ambulances and fire trucks. The
designers outlined the following pressing concerns: 1. No safe method is currently available for
transporting infants whose parents are immobilized in an accident. 2. The only option is to have a medic
hold the infant while en route to the hospital. 3. If the parents are not incapacitated they can hold the
infant, reducing the liability of the fire department, and 4. Currently there is a restraint system for toddlers,
children classified in the 20-80 lb. range, but this system could definitely use some refining.

National Child Passenger Safety Week 2000 reported that traffic crashes are the leading causes of death
for children of every age. Statistics indicate that restraint use in non-commercial vehicles for children from
birth to age one is 97 percent, and 91 percent for children between the ages one to four, which is fairly
high [2]. However, on a small child, the adult lap belt rides up over the stomach and the shoulder belt cuts
across the neck. In a crash, this could cause serious or even fatal injuries. So, even though safety belt
use is high for children the ability for these belts to actually reduce injury in the event of an accident is still
questionable.

The National Fire Protection Association (NFPA) reports that there is an average of one death and 307
accidents per week in emergency transportation vehicles [3]. The current option for transporting children
weighing between 20 and 40 lbs. in emergency vehicles is the use of a toddler seat that can be accessed
by pulling a back seat cushion down. The child is then placed on the seat and secured with a harness
seat belt. There is, however, no device or seat to securely transport infants between 5 and 20 lbs. in
emergency vehicles. Based upon the concerns of stakeholders on the team and the research regarding
emergency vehicle safety, the following problem statement was created: to design and manufacture a
seat for infant (5-20 lbs.) and toddler (20-40 lbs.) passengers that will fit inside the existing adult seat
used by first responders in order to provide secure transportation in the ambulance.

The Team and Its Members
One of the primary roles of industrial designers is to shape the interactions between users and objects by
considering diverse questions [4]. In this particular life-saving product, which has strict regulations and
limits, generating diverse conceptual ideas had to be carefully considered by the designers. The design
team focused on exploring possible design solutions that would satisfy the problem statement and meet
the safety requirements of transporting passengers in emergency vehicles. Delivering fresh concept ideas,
2D illustration and renderings, 3D CAD models, and 3D appearance models were the primary roles of the
design team.

With their first hand experiences addressing the realities of using existing child-restraint systems, the
firefighters played a significant role in bringing their concerns about safety and regulations to this critical
project. They also provided context-specific research access to ambulances and potential users of the
proposed seat. Interviews, site visits, and product observations were some of the most significant
research activities undertaken when crafting the problem statement for the development of the new
product. In addition, the participating experts were an integral part of the process of identifying user needs
and safety concerns.

One of the most important roles of engineers is to provide technology and appropriate mechanisms to
make products work efficiently and determine the reliability of the product [5]. At the end of the contracted
design phase, ESG Engineering, a local engineering company familiar with the requirements and
regulations for seating products, was contacted to help develop the mechanism required for the infant
seat. The engineers collaborated with the project leader and stakeholders to evolve the concept
presented by the original design team to meet the safety requirements of transporting passengers in emergency vehicles. Delivering fresh concept ideas, 2D illustration and renderings, 3D CAD models, and 3D appearance models were the primary roles of the
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The primary roles and responsibilities of business and marketing experts are to determine the appropriate
database and collect relevant information for new product development, such as product cost and value,
consumer needs and user preferences, marketing strategy and management, sales strategy, public
relations, branding and advertising [5]. The independent business consultant on the team undertook
these tasks and provided the team with a concise executive summary. Based on this summary, the business expert and firefighters on the team acknowledged that this product offered a valuable opportunity to form a new company that would come to be known as Serenity Safety Products (SSP).

**Timeline and Deliverables for Design Phases**
It was a big challenge for the design team to develop a new product which has strict regulations directly relating to a life-saving product within 15 weeks, assuming 10 hours a week for each of the three designers. The implementation timeline for design process and design deliverables were outlined by the faculty and approved by the entrepreneurs in the contract document. There were 4 main phases as shown below (figure 1): 1) understanding the context, 2) concept exploration, 3) concept development, and 4) rapid prototype and documentation.

![Figure 1. Implementation timeline.](image)

**Phase 1: Understanding the context**
Based on the data and problem statements demonstrated at the brainstorming session, the design team drew many thumbnail sketches exploring possible mechanisms and functions of the seat through discussions. At the request of the design team, two existing chairs and a standard infant seat were acquired and measured. The design team also obtained information about the structure of the metal frame and the manufacturing materials used. From this product observation and reverse engineering, the design team discovered that the biggest challenge would be fitting the infant seat into the limited space underneath the regular chair.

![Figure 2. Brainstorming session.](image)

**Phase 2: Concept exploration**
During phase 2 the design team started exploring possible concepts through discussions. Detailed renderings or well-developed sketches were not necessary at this stage. The focus was on the functionality of the seat, as well as a loosely defined aesthetic image of what the product would look like. Eventually, illustrations explaining the selected concept mechanism and a few renderings were created by students to help label and define the features of the proposed design such as the location of the infant seat, sliding mechanism, retractable seat belts, and a toddler seat built into the seat back.
Phase 3: Concept development
Based on the illustrations and renderings, a rough 3D CAD surface model, with dimensions measured from the current seat, was built in order to demonstrate the mechanism and functions. The key point of this activity was to assess the maneuverability of the infant seat from its stored position underneath the seat cushion to its in-use location, which according to government specifications must be at a 45-degree angle. Testing was done with a concept utilizing two gas springs that allowed the safety seat to be pulled out from beneath the seat cushion and locked into place. CAD modeling confirmed the potential of this mechanism to meet the targeted specifications. The design team then presented renderings that included details and color of the main seat, baby seat, and buckle clasp for the infant and toddler.

Phase 4: Rapid prototype and documentation
Next on the agenda was to create a study model of the chair to demonstrate the functional feasibility of the mechanism. It was a challenge for the design team to figure out the mechanical aspects of the design and produce a functional study model without the input of a mechanical engineer. The final mechanism design was based upon two rails and a pair of gas springs that allowed the infant seat to be pulled forward (with a squeeze release of locking pegs), aligned with rails, and then locked into its final position with the two (reengaged) pegs. This concept was illustrated and functional in the study model, but the design needed further optimization and parts reduction. Following study model development, the designers consulted with the stakeholders on the team to ensure feasibility and get feedback.

Systematic Solution: Integrated Innovation
The Integrated Innovation Model was created by InnovationSpace, a multidisciplinary design research laboratory at Arizona State University. It has been used as an exceptionally effective guide for the process of product development that leads to more holistic solutions to everyday problems. The model is comprised of four key questions that are required for systematic consideration. 1. Is the product valuable to users? 2. Is it possible through engineering? 3. Is it desirable to business? and 4. is it good for society and the environment? [6]. All of these questions were asked and answered collectively by the team.
members, the results of which were illustrated in the summary of the business proposal provided by the marketing expert.

![Figure 6. Integrated innovation model by InnovationSpace.](image)

What is valuable?
The Guardian Safety Seat Pediatric Restraint System is the first child-safety seat designed to accommodate children of all ages and sizes. With the Guardian Safety Seat, children from newborn (5 lbs.) up to 90 lbs. can be safely seated and restrained in a 5-point harness within the emergency vehicle with one seat. Currently there is no other seat that will allow emergency technicians to safely transport infants and toddlers while protecting the liabilities of the emergency transportation agency. This gives Serenity Safety Products much more than a competitive advantage in this market. It sets the company apart from the minimum standard and puts the safety of the child first.

According to Form 20-F Sec Filing by Pyng Technologies Corp, there are approximately 48,000 ambulances currently registered in the US [7] alone as well as over 75,000 registered fire trucks. In addition, there are approximately 20 new fire trucks and 15 new ambulances being put into service daily. The target market for the Guardian seat is organized into three segments: municipalities, manufacturers, and private service providers. All major municipalities in the US have a self-insured liability when it comes to their emergency departments. Municipalities have a vested interest in retrofitting their current fleets with the only device available that eliminates their liability and most importantly protects the safety of the pediatric passengers. Emergency vehicle manufacturers will have a vested interest in providing these seats to their customers, as well as making them available to private companies in order to comply with the specs of the municipal clients to maintain their business. Private service providers that lease their services to different cities and counties will also be driven to comply with the new safety standards.

![Figure 7. Final design solution.](image)

What is possible?
By providing a single solution to all age groups and sizes of pediatric passengers, Serenity Safety Products sets itself apart from any other technology. With the ability to safely stow away the infant seat and toddler seat in one unit the emergency technician can focus on the task at hand without being distracted by another apparatus to utilize. With the ability to accommodate such a large range of pediatric passengers, the Guardian also provides a safe and secure five-point restraint system for all weights and sizes. This will become the standard for safe transportation of all children thus allowing the emergency companies the ability to provide a truly safe and effective means of care.
What is desirable?
There are approximately 48,000 ambulances registered in the US. Each year approximately 15,000 accidents and an average of 1 fatality per week occur while these vehicles are responding to emergency calls. Oftentimes it is necessary for children or infants to accompany ambulance patients during transport. The product that resulted from this project, the Guardian Safety Seat, is for the well child or infant that must accompany a patient (i.e., adult parent or care provider) being transported in an ambulance. As advocates of public safety, emergency workers are charged with the responsibility to provide safe transportation in ambulances for people of all ages. Due to limited storage space and time-sensitive emergency situations, standard automotive child and infant safety seats and time consuming restraining belts and products that attach to and occupy the gurney in ambulances are not practical.

Various child passenger safety organizations’ data state that automotive child and infant seats are installed incorrectly over 95% of the time. The emergent nature of ambulance and emergency scenes require a quick, safe, and easy method of safely securing children and infants in ambulances. The design of the Guardian Safety Seat eliminates the possibility of incorrect installation of the infant carrier because the carrier is already attached to the main seat frame and simply lifts and locks into the recommended 45-degree angle. The seat can be deployed in the infant or child configuration within seconds, thereby saving time in an emergency situation. When not in use, the infant carrier is hidden from view within the interior of the attendant seat, where it is stored until needed, and therefore does not occupy any precious ambulance storage space.

What is good?
For years, emergency workers including paramedics and firefighters have struggled to find a quick, safe, and effective method of safely restraining children during transport in emergency vehicles. Although various systems have been used and tested for transporting children in emergency vehicles, none have been convenient, simple to use or have been able to accommodate the entire range of the pediatric passenger. The need for safe transportation of children is imperative, and this product provides that solution by affording the emergency technician the ability to secure the child while focusing needed attention on the injured victim.

The Safety Seat frame and other components were manufactured from 10- and 12-gauge cold rolled steel that is 100% recyclable and finished with powder coating. The frame consists of both TIG and MIG weldments. The infant carrier is made of injection-molded Formolene 6507N, a medium-impact copolymer of polypropylene. Environmentally friendly BioFoam was used for the cushions, eliminating Polyurethane chemicals. A natural essential oil of grapefruit seed extract was embedded into the finished infant carrier during the molding process to ensure the infant carrier surfaces are resistant to bacterial growth. The foam cushions and pieces were made of BioFoam using a seamless "tuffskin" process. Most fasteners and other parts are standard automotive or industrial grade.

What did we learn? Concluding lessons for future product development partnerships
There are several possible approaches to the new product development process, which often depend upon who initiates the project. The previously described process represents a stakeholder idea resulting in an industry/academia partnership. This approach afforded many possibilities and produced various challenges.

This project was initiated by entrepreneurs (local firefighters and a marketing expert) who contacted an industrial design faculty member to visualize their idea and to assist in developing a business plan. A team of designers capable of the task was assembled, the challenge was identified and a timeline for the project was agreed upon. After the product design phases were completed, the team identified a local engineering group with expertise in vehicle seating to consult on the consequential phases of the project, particularly with feasibility issues relating to technology and mechanisms.

Contextual product-usage prototype testing was conducted with children, an infant, and firefighters. These tests by the engineering team were videotaped and the resulting demo video was used to present the new product in print and electronic media. Several seat crash tests with prototypes were conducted in
Indiana at the Center for Advanced Product Evaluation (CAPE) with dummies and the product successfully passed the safety test (Figure 8). Marketing strategy and business plan were then clarified based upon the results of the testing and the design. Final design modifications required for manufacturing are currently being undertaken by the project leader.

Strengths
A retrospective view of this project reveals various strengths, weaknesses, and learning opportunities for future such collaborations. For example, this project provided invaluable lessons for students, faculty, and the entrepreneurial stakeholders in terms of its progression from idea to manufacturable product and new business development. A few other experiences that directly benefitted the students included the following:
1. The opportunity to work with firefighters, engineers, and business experts
2. Learning to working within the many strict regulations of life-saving products
3. Generation of intellectual property, including a patent on which both students are named
4. Connections for possible future projects with the entrepreneurs

Those experiences that directly benefitted the entrepreneurs illustrate potential selling points for future such collaborations and include the following:
1. The opportunity to work with and learn from/faculty and students
2. Access to university resources, facilities, and network
3. Fresh, innovative ideas from students and faculty at the cutting edge of product development research and practice
4. Education about the value of design and in the process of new product development
5. Research and visualization that contribute to new business development

Challenges
The biggest challenge faced by all participants was the development of an innovative product within such a compressed timeframe. Although the design concept deliverables were completed within the 3 months originally contracted, additional engineering of the requisite mechanisms and required safety testing and iterations are still underway. These unforeseen additional steps constitute a necessary part of the process but one that has compromised the original projected product launch date of July 2007. Considering that the additional time-to-market is a result of the need to ensure child safety, future projects should allow time and resources for such testing.

The other primary obstacle faced during the development of this product was timing the input from the engineering team. As described above, the first phases of design development were undertaken exclusively by the design team and stakeholders and, once concluded, brought to the engineering group. In this particular case, the nature of the project contract did not allow for immediate identification and inclusion of the engineering team. This approach resulted in a number of necessary iterations of the original design concept due to engineering and safety specifications. Given the chance to begin the project again, the design team agreed that involving engineers in early brainstorming sessions and concept generation would have been ideal.

Future Considerations
Based upon the experiences and issues previously described, the following considerations are offered to those educators who may have opportunities for industry/academia partnerships with multidisciplinary teams:
1. Seize the opportunity to educate the stakeholders in the project. If the client/partner is not familiar with the product development process, they will not be able to ask the right questions and budget time and resources accordingly. Lead the client/partner through the process and, chances are, they will continue to be a client/partner in the future and even help you identify new ones.
2. Ensure that all steps of the process are considered, discussed, and negotiated at the project outset. No one likes surprise, particularly when it comes to product launch dates or budgets!
3. Bring all stakeholders for the project into the process as soon as possible. Valuable time can be lost updating team members and/or revisiting design solutions that lack feasibility.
4. Team formation is paramount. It is important to consider what value each member brings to the team and what essential role each will play. Within the academic context it is also necessary to balance the business needs of the client/partner with the academic needs of the students.
5. Know your network and resources. It is impossible to predict every expert or facility that you may need, so know what all of the possibilities are. Not only does this demonstrate value to your client/partner, but if an obstacle arises you will be prepared to overcome it.

References