Design driven product development, from Concept to Completion

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***Abstract*– Throughout history, ideas, methods, and products have been developed to accomplish tasks in a new, faster, more efficient or better way. Radical innovations or improvements create new paradigms, new approaches, and spawn almost impossible goals. This paper describes how the traveling hardships of a global management consultant prompted the conception of an accessory, compatible with carry-on suitcases, that could be used by any traveler. The consultant inquired the Dean of the College of his alma mater about the possibility of having faculty and students participating in the development. The endeavor started in early 2015 and transformed the idea of an alumnus into a product that is currently being commercialized.**

***Keywords*– concept, completion, innovation, implementation, manufacturing.**

I. Introduction

Since the beginning of human evolution, a trait that distinguishes the species is *innovation*. Throughout history, new concepts, methods, or products have been developed to accomplish tasks in a new, faster, more efficient, or better way. It is part of human nature to invent; it is evident it happens, but why it occurs is sometimes less clear. One popular school of thought is that "*necessity is the mother of invention*", or that the lack of alternatives leads to innovation. The author of this proverbial saying is not known. It is ascribed to Plato and it does appear in translations of Plato's Republic [1]. There is a constant struggle to find innovative ways to do new *things* in order to reach further, to prove that it can be done. Radical innovations or improvements create new paradigms, new approaches, and spawn almost impossible goals.

Engineering, Engineering Technology, and Manufacturing academic programs might vary in content and delivery, but most of them share one essential concept: *innovation*. Innovation can simply be viewed as transforming ideas into reality. Within academic rigor, ideas are labeled as designs, reality as products. Synthesizing a design, properly documenting it, assessing the options for its implementation, and perhaps even how to package, distribute and eventually disposing or recycling the resulting products, are all elements of these academic programs.

Design and Engineering entail translating ideas into concrete concepts, transforming them into something plausible. When concepts appear to be feasible, further scrutiny and examination will be required. Triggered by the opportunity to gain new customers or entering into new markets, designers and engineers mature ideas and attempt to consolidate them through theoretical principles. Engineering Technology and Manufacturing focus on implementing the validated concepts and specifications, verifying and reassessing all envisioned elements, in order to transform them into tangible, profitable goods. Making use of adequate and available technologies, materials, processes, and human resources, with the most efficient and effective approach, allows transforming the finalized confirmed plans into products, turning concepts into results –to completion.

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II. Concept

It all started with the hardships a global management consultant experienced while traveling. Not a casual traveler, who had accumulated four million air miles during 5,000 flights covering all 50 states, this individual was frustrated because of the difficulties of having to balance a laptop between the legs and not having where to place a snack or drink for lack of a suitable space in boarding areas. After unsuccessful searches to find an existing product that could be useful to tackle the problem, the idea originated while waiting for a connecting flight.

The essential concept was to add a shelf-like accessory to the telescopic handle poles of a standard carry-on suitcase to provide a suitable platform, of about one square foot, to accommodate common things travelers use. The accessory was to be unobtrusive, foldable and retractable. When not in use, it would be stored between the poles spacing within the suitcase.

Conversations with family and friends about the idea strengthened the concept further, to the point of encouraging the development of a rough prototype. The prototype worked, the innovation was promising, but brought the realization that additional assistance will be needed to implement it, to take it to completion.

III. Evolution

During a visit to his alma mater, Western Illinois University, the consultant queried the Dean of the College of Business and Technology about the possibility of having faculty and students conducting feasibility and marketability studies related to the idea, pursuing to validate the concept. As a member of the College Advisory Board, distinguished alumnus and benefactor, the request was immediately considered by the Dean and the College Development Officer.

The Development Officer arranged meetings with faculty from different areas inside the College and established basic agreements with the consultant, or simply the alumnus.

Including non-disclosure clauses, the agreements involved a series of general goals:

- Thorough analysis of the prototype, assessing pros and cons, in order to determine refinements or alternative approaches
- Creation of models and technical drawings to fully document the concept
- In-depth search of existing (current) patents protecting devices posing similarities in either approach or function
- Collection of available data of sales volumes of carry-on suitcases and number of travelers through mayor hubs in the United States (U.S.) in order to determine trends

Officially beginning during the Spring of 2015, the project involved the participation of one faculty member along with graduate and undergraduate students from Engineering and Technology.

Two teams of graduate students and one team of undergraduate students were formed. The students were enrolled in courses which objectives were compatible with tasks related to the project. One of the graduate teams was to focus in patents research while the other was to concentrate on luggage sales and travelers' statistics. The undergraduate team would tackle the prototype analysis and the development of engineering documentation.

As all tasks were going to imply expenses, the alumnus agreed to cover all costs and to provide funds, in the form of donations towards Engineering and Technology to support assistantships, scholarships, and student travel.

The patent search graduate team worked for the first eight weeks of the semester conducting on-line and State library assisted searches. Existing patents of accessories that could be added or attached to luggage were found, but none with the characteristics of the alumnus concept. The other graduate team, collecting industry and government data, was able to find public-domain information and some that require a membership on Statista, a German company specializing in market and consumer data. The data was used to develop forecasts that were used to determine trends and estimates. General outcomes are illustrated in Fig. 1 [2] and Fig. 2 [3].

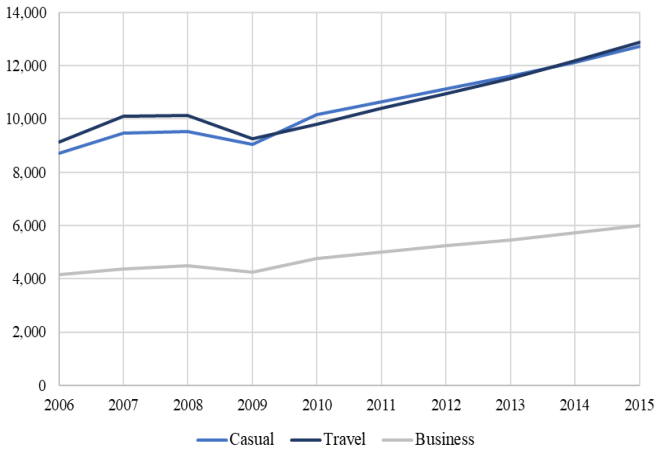

Fig. 1 Retail Luggage Sales (millions) by Segment 2006 to 2015.

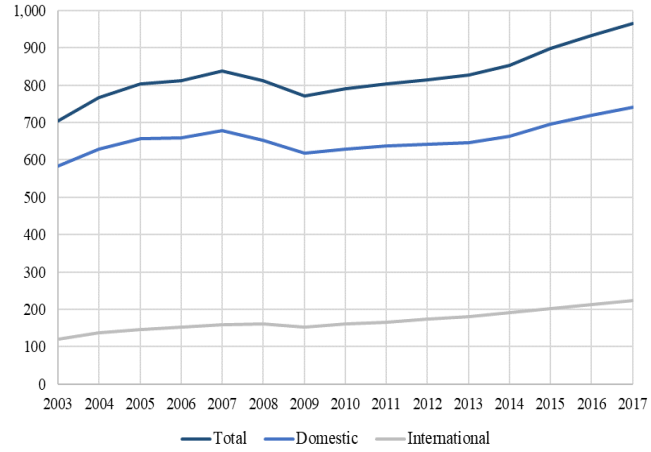

Fig. 2 U.S. and Foreign Airline Passengers (millions) 2003-2017.

The team of undergraduate students analyzed the prototype created by the *alumnus* and generated a series of proposals to improve it and ensure the desired operation. As the different elements of the prototype were modeled and virtually assembled, static and dynamic Finite Element Analysis (FEA) reviews and functionality simulations were conducted. The computer models led to the creation of technical drawings and the development of engineering specifications. Results of all evaluations, along with preliminary schematics and supplementary documentation were submitted to the *alumnus*, who in turn used them to complete the submission for a patent pending application.

All virtual models, one partially depicted in Fig. 3, and proposed improvements to the original concept were well received by the *alumnus* and led to an additional validation goal: producing a full working prototype through the use of 3D Printing techniques, illustrated in Fig. 4.

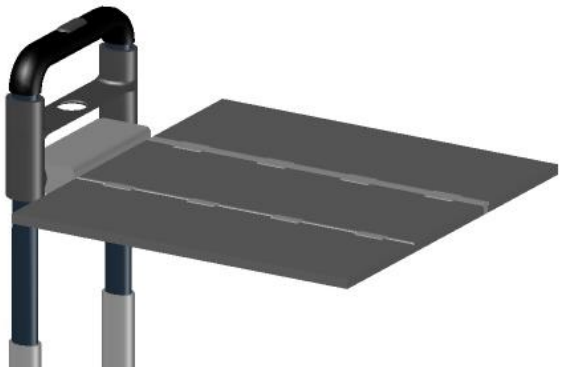

Fig. 3 Concept Model.

Fig. 4 3D-Printed Prototype.

Although the prototype was produced according to the enhanced models, some elements had to be adjusted to fit a particular carry-on suitcase brand. This was a known complication, as the variability of carry-on casings geometry is extensive. Nonetheless the prototype functionally further validated the concept. The *alumnus* was elated with the performance results and wanted to further refine and expand the idea and the validation. After several brainstorming sessions with the leading faculty member, three different additional goals were defined:

- Creation of models and prototypes compatible with other different popular carry-on brands
- Development of models and prototypes for an after-market kit that would allow consumers to retrofit their existing carry-on suitcases to adapt the accessory
- Design of a new, slightly smaller (10"×10"), variant of the idea that could easily be attached or detached onto the poles of carry-on luggage

Creating prototypes compatible with popular brands was aimed to explore interest from luggage manufacturers to license the idea in order to add the functionality to existing product lines, while developing the retrofit kit was aimed to attract consumers that would want the added functionality on their currently owned luggage. Both of the approaches related to the original idea were feasible as most issues had already been resolved, but validating the new approach was considerably more complex. To continue the project, it was necessary to:

- Form new student teams to participate in the project
- Secure additional funds

Funds were provided to support assistantships and to cover additional expenses, while the leading faculty member undertook the initial design of the new concept.

As the project progressed at the University side towards the end of 2015, the *alumnus* continued exploring ways to promote the idea working with marketing firms, launching a website for a newly created Limited Liability Company (LLC) after the concept, goDesk®, and hiring the services of a specialized law firm to secure the final patent.

All efforts were focused to unveil the new concept for the first time at the Travel Goods Show (TGS) in April of 2016. Participation in the trade show brought to light the fact that the attachable accessory was the one better received by attendants. After the show, the original idea was placed on hold, and the focus switched to a product that could be easily attached or detached onto the poles of carry-on luggage. Fig. 5.

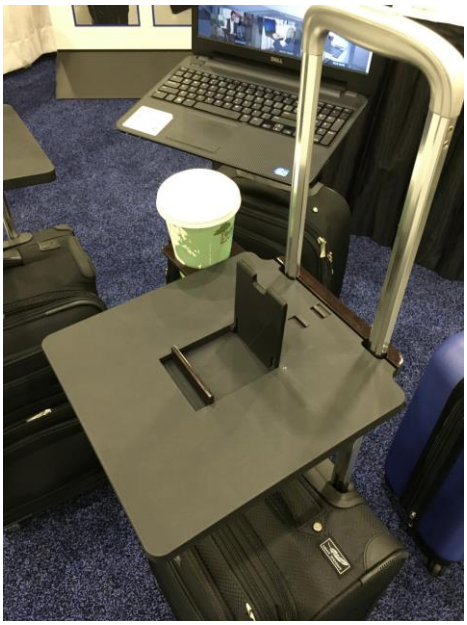

Fig. 5 Attach/Detach prototype.

Three attach-detach prototypes had been completed for the trade show. The prototypes worked well with the carry-on suitcases used for demonstrations during the show, but were not universal. The challenge was then to adjust the concept further, making the device as universal as possible and easy to operate.

The problem was not trivial and required hundreds of hours of research and development.

Most importantly, carry-on pole configurations had to be thoroughly ascertained. A new team of students, graduate and undergraduate, conducted the research. The team was able to find information on-line, performed field studies with luggage vendors, and directly gauge carry-on suitcases purchased or borrowed from regional stores. The *alumnus* also gauged several other carry-on suitcase models at every opportunity and shared the findings with the team of students. After analyzing all gathered information, general geometric characteristics for the accessory were finalized.

Meanwhile, the leading faculty concentrated in conceiving different approaches, devices, and mechanisms that would guarantee a simple and easy approach to attach and detach the accessory. Variables of the required operation were known, related to a cantilever beam, but translating the variables of the cantilever problem to the geometric shapes of the accessory, its function, operation, and use, required several iterations.

Once options and approaches were assessed, and a final mechanism integration was deemed feasible (further refined by thoughts of an undergraduate student) the concluding geometric product shape was modeled, analyzed, prototyped, and tested. Final analyses and virtual simulations were conducted to ratify all findings. Fig 6 depicts results, safety factor rates, of a strength analysis of the final configuration.

By October of 2016 the final patent (US 9498055 B2) had been obtained. Incorporating 15 provisions for the original integrated concept and five for the attach-detach option, securing the patent unlocked genuine commercialization potential.

With the concept fully protected, plans for participating in the 2017 TGS begun. The intention was to promote the universal attach-detach version. Additional features had been added to the accessory, like a cup holder and a device stand, which increased the complexity of generating improved prototypes with the technology available at the University. It was then decided to outsource the production of a series of high-end prototypes to be ready for the show. The product generated wide interest by attendants to the trade show and the success reinforced and further validated the idea, reassuring that the accessory had commercial potential.

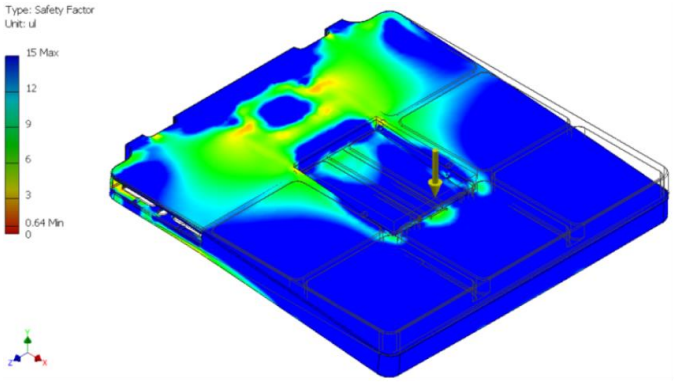

Fig. 6 Strength Analysis.

Supplementary alterations and improvements, based on comments and feedback from attendants at the trade show, were incorporated into the design. The last validation phase consisted in the development of engineering specifications for hardware components, complete parts documentation, and the refinement of the models of all the elements that conformed the accessory. Fig. 7.

IV. Completion

With the idea comprehensively validated, the challenge at that point was to determine how to mass-produce the accessory in an economical and efficient way, to make-it-so [4]!

The *alumnus* had established contact with regional manufacturing companies, from the plastics injection molding sector, capable of producing the accessory. The leading faculty participated during preliminary meetings and conversations, and was made aware of concerns from the manufacturers.

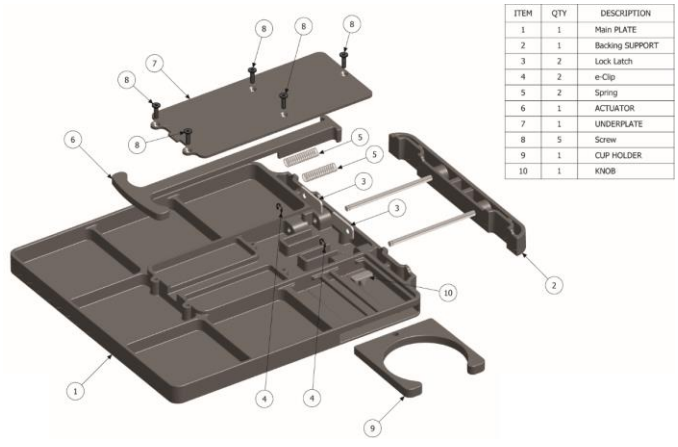

Fig. 7 Final Array Model.

Although the geometric constraints and tolerances related to all the components of the accessory had been assessed and verified, they were suitable for the Fuse Deposition Modeling (FDM) and Selective Laser Sintering (SLS) processes that had been utilized for producing prototypes, not so for mass production.

FDM and SLS processes for low volume production runs are generally more economical than a forming process like injection molding, which will be preferred for high production volumes. The generation of shapes with complex geometric constraints could be difficult through injection molding, particularly if extreme cavities are present in the intended shape. Furthermore, injected molded parts require wall thickness uniformity to prevent deformations and distortions; not a restriction of SLS.

After considering different proposals, engineers and toolmakers from the company that was selected for undertaking production (Toolroom, Inc.), the faculty member, and a new group of students, initiated an additional refinement phase towards manufacturability.

Modifications and refinements concluded by the end of the Summer of 2017. Work required alterations to some features and the modeling of new elements but the overall functionality was maintained. The finalized array was an extraordinary implementation of design for manufacturing and aimed to the simplest possible assembly (DFMA).

While the tooling production took place at the Toolroom, Fig. 8, vendors for two other custom-made components and suppliers for standard elements, like screws and springs, were selected. The first total integration of parts from the initial production run was successfully completed by the beginning of the Fall of 2017.

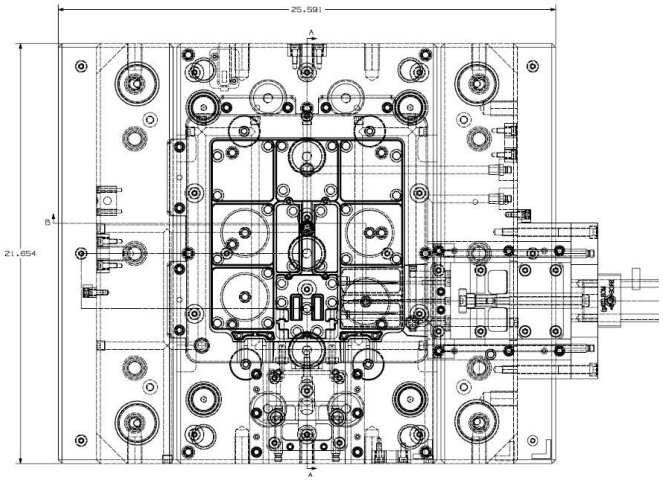

Fig. 8 Main Plate Injection Mold (Bottom).

The new product was thoroughly tested by the *alumnus* and at the University. The *alumnus* conducted realistic field tests, traveling with the device for about two months. Simultaneously dynamic and stress tests were conducted by the University faculty leader and a new team of students. Some tests examined the behavior of the accessory under extreme conditions, applying static loads of an excess of 50 pounds, without suffering failures, as illustrated in Fig 9. Under normal conditions, the accessory would not experience loads of such magnitudes, but the intention to overload it was to ensure safety.

During the testing stage, assembly verifications were also conducted. Alternatives and procedures were assessed, and assembly operations documentation were created and verified by a team of graduate students. Packaging options and labeling were also progressing.

One important aspect of the overall effort was the fact that the *alumnus*, from the beginning, wanted all of the activities related to the development of the formal concept and its completion to be conducted and produced in the United States, preferably within the Midwest.

By late February of 2018 it was time to return to TGS. Within a two-year span, from the 2016 trade show to the one of 2018, the idea that originated it all was presented as a full, protected, branded, and legitimate product, Fig 10. Product samples were distributed to selected participants, representing manufacturers.

Through 2018, assembly procedures, packaging and distribution were ironed out further. Also, the *alumnus* tested options to mask manufacturing blemishes on the surface of the main plate through the application of a branding decal.

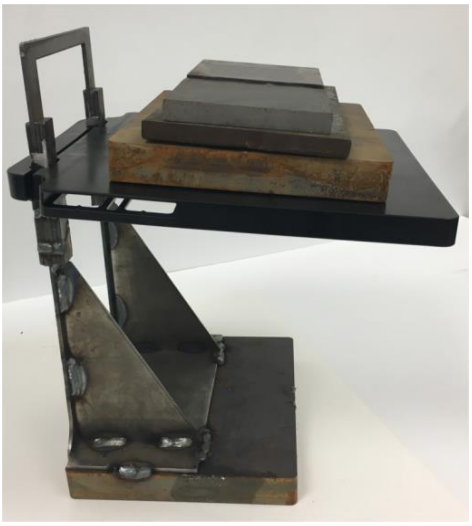

Fig. 9 Dynamic Testing.

Fig. 10 goDesk product.

By early 2019, all details resolved, the launch of the product through the LLC web portal (yourgodesk.com) was readied for the first Monday of March. Due to scheduling conflicts, the company in charge of assembly and packaging the product was not going to be able to fulfil requirements, so the alumnus once again turn to the University for assistance.

The leading faculty member was able to recruit a group of students and set-up a makeshift mini-operation to assemble and package the product. The assembly/packaging run, for a batch of 250 units, took place on March 1st of 2019 and provided the opportunity to refine assembly-steps instructions and operational documentation, Fig. 11.

Fig. 11 Assembly Run at the University.

After the assembly run at the University, sales through the LLC portal went on line as planned. Towards the end of 2019, specifically on November 21, the first sale through Amazon took place. Fig. 12 depicts the product listing and description on the Amazon website.

Fig. 12 goDesk at Amazon.

As sales improved through Amazon, a new company was approached to undertake assembly and packaging operations. Personnel training for the new company employees, to assemble and package products, took place in early March of 2020. As the Covid-19 crisis started, work related to all activities slowdown or stopped.

One encouraging event occurred towards the end of April 2020. The LLC was approached by a leading TV marketing group. An agreement was stablished and a National promoting campaign started. By August, a TV commercial to advertise the product in major cities on popular networks/stations initiated. The commercial is narrated in part by Kevin Harrington, the original Shark from Shark Tank. Fig 13.

Fig. 13 goDesk Commercial.

V. Conclusion

First and foremost, all activities related to the project follow the *concept to completion* philosophy: the idea of an *alumnus*, validated and readied for implementation by his efforts along with those of a University professor and his students.

The project entailed activities within the fields of Intellectual Property, Additive Manufacturing and 3D Printing, Data Analysis, Engineering Analysis and Design for Manufacturing and Assembly. It also involved the assessing of materials, manufacturing processes and specifications, and the outlining of detailed documentation. Overall, several of the vital concepts that Engineering and Engineering Technology programs intend to instill in students. During four semesters and three summers, a total of 53 students were involved.

Associations between industry and academia are not a novelty, rather a necessity. The implication is not just from an academic point of view, but an irrefutable proof of how it is possible to use or implement available resources and technology in the most efficient and effective manner, even to the point of being competitive not just locally or regionally, but truly at national or international levels.

As of today, the goDesk LLC is re-launching the sales campaigns of the attach/detach version of the product, referred to as the goDesk GO, and considering the launch of a carry-on product, which includes the fold-retract version, goDesk Pro, of the original concept.

Necessity is the source of innovation and "imagination more important than knowledge" [5].

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