AboveBoard

Improved mobility. Increased autonomy.

1) Problem Statement/Research Question and Background

"Maybe you can make a new hospital table," my Aunt said when I told her about our class project. She recalled how her elderly father, diagnosed with cancer, had trouble getting in and out of his hospital bed. "The table could assist people maneuvering in and out of bed. Plus," she added, "all of the hospital tables I've seen are cheap looking and confusing to use."

Further research revealed similar sentiments. Institutional patients and staff value existing overbed tables for their top surfaces. Yet other overbed table features and functions present opportunities for improvement in design, durability, and usability. One study in particular conducted by Clemson students and presented in the Health Environments Research and Design Journal (HERD), investigated overbed tables and the categories of usage, mobility, size, and design preference amongst healthcare providers and users. Figure 1 outlines the study's key findings.

The refinements outlined in HERD regarding commercial overbed tables undoubtedly extend to the narrowly represented domestic overbed table market. The elderly, people with limited physical capabilities, and pregnant women prescribed bed rest are some of the many people who are bedridden. The major challenges of decreased functional mobility and self sufficiency can turn seemingly simple acts like reaching to ones bedside table for a sip of water, or getting oneself out of bed into laborious chores. An assistive overbed table could prove useful in such situations by increasing individuals' ability to engage in these tasks with an increased level of independence.

Current research does not provide information about in-home overbed table preferences. Market research revealed few products available for purchase. Most merchandise has a clinical aesthetic unsuitable for the home, not to mention its questionable reliability under load and ease of use. Products currently on the market are designed to hold unspecified products, and often need to be moved by other people. The product we are creating seeks to increase independence for the user and provide them not only with a functional place to keep their things, but as a device to provide them exactly as much or as little assistance as they need. In the home, a person may use its stability to support themselves moderately, letting their body and the device share the load as they sit to stand, or they may only require minimal assistance, providing them with just the little bit of extra help they need to be independent.

We used this research, along with the information gleaned from in-person interviews, to design our product - an adjustable, in-home assistive swivel overbed table. Key findings from the study show that the primary function of the tables is to facilitate eating, personal hygiene, and a storage place for important items. While not all features may be used at once, patients reported higher satisfaction with tables that had ample space with the ability to extend and a place for cup holders. Having a space available to them to use for activities they need or want to do will allow the patients to feel empowered by increasing their perceived autonomy and ability to interact in their environment. Research has shown that perceived autonomy and some participation in self-care and management skills contribute not only to supporting patients' self-management, but increases their health related quality of life, motivation, and ability to cope with their condition (Raaijmakers, Martens, Hesselink, de Weerdt, de Vries, & Kremers, 2014).

 **Discharged Dan**	 **Pregnant Pam**	 **Neurodegenerative Nancy**
Dan is a 62-year-old man with a work related spinal injury. He needs help from his wife with bathing, dressing, and transitions out of bed and from sitting to standing positions. He finds it particularly difficult to get out of bed without bending and twisting his spine. He has been taught in the hospital how to properly get out of bed, but finds it difficult to push himself off the bed and stabilize himself before walking. Having a device that is stable enough to help him get to the edge of the bed and out of bed without breaking his spinal precautions would facilitate his independence in using the bathroom without his wife's assistance. Without having to attend her husband's activities of daily living, Dan's wife could return to work sooner, and so could Dan as his adherence speeds up his recovery.	Pam is 38 and 7 months pregnant with twins. She is on bed rest until she gives birth, but still needs to get up to use the bathroom and make meals for herself. Her job flexibility allows her to work from her computer at home, but she finds it difficult to keep all the items she needs within reach, and does not want to strain herself. She also has difficulty getting in and out of bed and stabilizing herself before walking. She would benefit from a device that could assist her in working and eating while resting and to help her transfer in and out of bed.	Nancy is a 54-year-old woman diagnosed with Multiple Sclerosis 10 years ago. Her condition results in her experiencing extreme fatigue, weakness, vision changes, gait impairments, bowel and bladder dysfunction, and some sensory loss in her lower extremities. She needs to use a bedside commode at night to safely and successfully use the bathroom. Due to her symptoms, She would benefit from a device that would provide her with a moderate level of assistance in getting out of bed and achieving stability while transferring safely to the commode. Nancy used to enjoy running a craft club at the local art store, but now enjoys that activity by doing small crafts in her room; she would benefit from a table that she could use as a working surface that she does not have to lift and move out of her way when she wants to rest. This would allow Nancy to participate in an activity that she values and enjoys without having to compromise her health and add unnecessary movements that would increase her fatigued and other symptoms.

Chart 1 - Three user personas illustrating AboveBoard's universal design and significance.

2) Methods/Approach/Solutions Considered

We researched the hospital table and assistive device markets for design inspiration, creating mood boards to organize our ideas. Our first round of concepts included assistive walking products, such as walkers, with varying table top surfaces. Most of these designs would have required the user to clear the table top surface before using the assistive device. Having to remove objects in this way would be cumbersome. Our next round of iteration focused more on tables and assistive bed rails, where most of the designs utilized caster wheels. The biggest challenge for us at this point was determining how wheels would provide enough support to users looking to lean on the overbed table as an assistive device. Our third and final round of iteration resulted in our final product. We conceptualized ideas via sketching, CAD, and foam to produce diversiform tabletops and bed rail attachment mechanisms before rendering our final design.

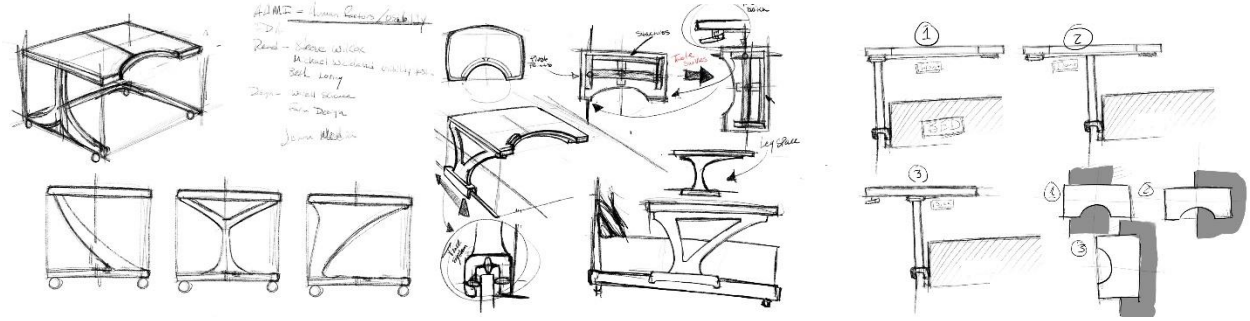


Image 1 - Some of our sketch ideations.

3) Description of Final Approach and Design

Our final product, AboveBoard, takes into account teacher assessments, user feedback, and our insights from multiple rounds of iteration. AboveBoard acts as a piece of assistive furniture and provides optimal support to users maneuvering in and out of bed by using the bed's mattress for stability. Strategically placed ergonomic handles also facilitate moving in and out of bed. Our product's adjustable height and swivel features accomplish an aspect of Universal Design. These features allow for a diverse range of use by people with a varied range of abilities, people with decreased strength, limited functional grip etc. AboveBoard's base can also attach to either side of the bed's rails, and its reversible tabletop accommodates both right and left-handed users.

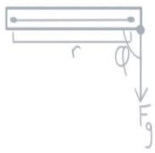
Image 2 - Final design render.

AboveBoard serves not only as an assistive product for people with limited mobility, but also as an eating and work surface for those who are bedridden. Its lightweight and user-friendly design incorporates lighting and recessed cup holders, along with an antimicrobial, non slip table top surface, and optional underbed storage for caregiver supplies. Lastly, AboveBoard's unobtrusive design makes it aesthetically pleasing for the home.

4) Outcome

We created a looks-like prototype which demonstrates size, movement, and usability. The final product will additionally be able to handle up to a 300 lb load. We used physics calculations and engineering simulations for more extreme user testing.

Calculation 1



$\tau = F_g * r * \sin \varphi$

Where:

R = 27in = .6858m

$\varphi = 90°$

$F_g = m * g$

m= 500lbs = 226.8 kg

G = 9.8 m/s^2

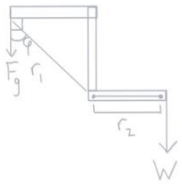
F_g = 226.8 kg * 9.8 m/s^2

= 2,222.64 N

τ = 2,222.64 N * .6858 m * sin (90°)

= 1,524.28 Nm

Calculation 2



$\tau = F_g * r_1 * \sin \varphi - (W * r_2) = 0$

Where:

F_g = 2,222.64 N

r_1 = 27 in = .8525m

r_2 = 45.85 in = 1.16m

Calculating φ:

Θ = arcsine (.5055 m / .6858m)

= 47.48°

φ = 90° - 47.48°

= 42.52°

Calculating torque:

$\tau = F_g * r_1 * \sin \varphi$

= 226.8 kg * 9.8 m/s^2 * sin(42.5°)

= 1,501.6 N

Calculating the counterweight:

1,501.6 N = W * r_2

W= 1,501.6N / r_2

= 1,501.6N / 1.16 m

= 1,294N

= 291 lbs

Chart 1 - Physics calculations.

Physics Analysis: In our first calculation we determined the amount of torque placed on the tabletop when being used by a 500lb user. We chose a high user weight variable assuming that most product users would weight less, and the tabletop would therefore be subjected to less torque. We calculated the torque as 1,524.28 Nm. This exercise provided us insight into the product's materials (see Section 5).

In calculation 2 we determined the counterweight necessary to keep the system from tipping over. We defined the system as our product plus an average queen size bed unit (box spring, mattress, bed frame, etc). The tabletop is in its fully open position as illustrated in the below diagram; we assumed the system would be most likely to flip at this configuration. A counterweight of 291lbs is necessary when the product is used by a 500lb person. We chose a high user weight variable assuming that most product users would weight less, and the necessary counterweight would likely be less. In addition to influencing our manufacturing material selection (see Section 5), this exercise led us to consider the possibility of weighting the adjustable rail placed between the boxspring and mattress with sand. However, the weight of a typical bed unit (mattress, rails, header/footer, etc.) would likely satisfy counterweight needs. Adding weight via sand could increase product manufacturing and/or shipping costs, or complicate in-home user setup. We therefore decided against this idea.

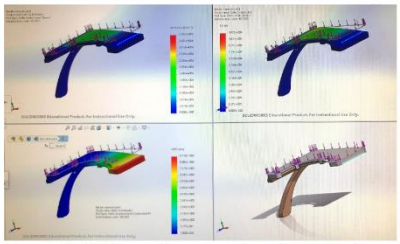


Image 3 - FEA results comparison for 300lb force applied to ABS tabletop.
Top Left – Stress. Top Right – Strain.
Bottom Left – Displacement.
Bottom Right – External Force Surface.

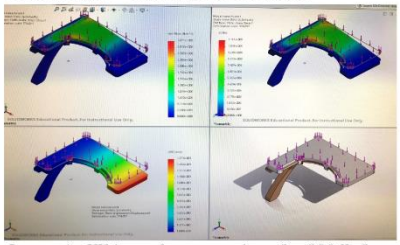


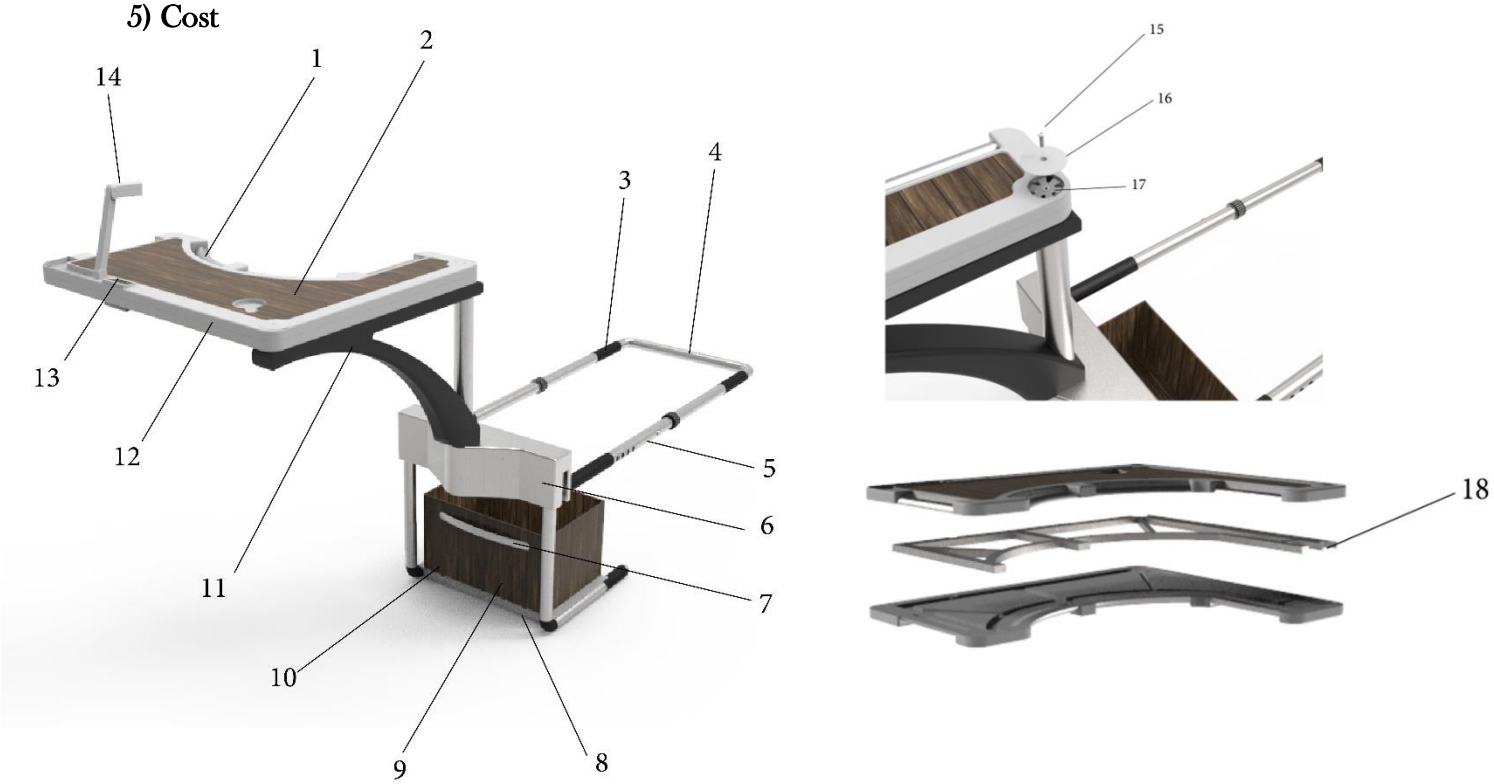
Image 4 – FEA results comparison for 300 lb force applied to alloy steel tabletop.
Top Left – Stress. Top Right – Strain.
Bottom Left – Displacement.

Finite Element Analysis: We performed a finite element analysis on our product's basic cantilever structure. We conducted tests with 300 lb and 500 lb forces applied to the tabletop surface where the tabletop was assigned ABS plastic and alloy steel for both forces, respectively. The structure supporting the table was assigned ABS plastic in the abovementioned scenarios. We decided to focus on the data relating to the applied 300lb forces, as most products on the market (rails, handles, poles, etc.) are rated to accommodate

300lbs. We decided to implement our FEA insights by adding a steel support frame within the tabletop surface part to assure our assistive product's durability. (See Section 5 exploded product model).

User Feedback: We used feedback from occupational therapists, physics and engineering professors, industrial design teachers, and caregivers to guide our ideation process and final design.

5) Cost



Component	Part Description	Material	Process
1	Handle bars	Alloy Steel	Drawing
2	Tabletop surface	Noryl	Immersion printing
3	Overmolds for improved grip and less slip	TPE	Injection molding
4	Adjustable bar placed between the box spring and mattress	Alloy Steel	Drawing
5	Twist lock mechanism on adjustable bar placed between the box spring and mattress	ABS	Injection molding
6	Adjustable locking mechanism attaches onto bed rail or bed frame	Alloy steel	Die casting
7	Handle on under bed drawer storage container	Alloy steel	Drawing
8	Tracking base for under bed drawer storage container	ABS	Injection molding
9	Under bed drawer storage container	Noryl	Injection molding and

10	Under bed drawer storage container	Noryl	Immersion printing
11	Pivoting support bar for table top	Noryl	Gas assist injection molding
12	Table top	Noryl	Gas assist injection molding
13	Outlet cover (internal components from McMaster-Carr)	Noryl	Injection molding
14	Folding table top light (internal components from McMaster-Carr)	Noryl	Injection molding
15	Alloy steel socket head cap screw	McMaster-Carr	
16	Table top cap for aesthetics and locking function	Noryl	Injection molding
17	Star Nut	McMaster-Carr	
18	Support frame within table top surface	Alloy steel	Stamped

Chart 3 - Bill of materials.

6) Significance

AboveBoard allows seniors and people with modified abilities improved mobility and increased autonomy. Research from Coats, Fath, Astill, and Wann (2016) states that as older adults age, they become less efficient in upper extremity eye coordination. They need more time and reliable objects to stabilize them to increase their safety. Furthermore, people of limited physical capabilities often feel their need for assistance makes them a burden on caregivers. As a result, they attempt activities that they are no longer capable of performing without assistance. This can result in falls and other injuries which lead to more serious and long-term complications to maintaining independence. AboveBoard helps mitigate these concerns, all the while placing caregivers in the position of providing oversight and some assistance without requiring direct, constant intervention.

7) Acknowledgements and References

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