BILKENT UNIVERSITY

DEPARTMENT OF MECHANICAL ENGINEERING

INDUSTRY SUPPORTED GRADUATION PROJECTS

2024-2025

10th YEAR BOOKLET

Printed in Meteksan Matbaacılık, May 2025

Publisher Certificate Number: 51344

Printing House Certificate Number: 46519

ISBN: 978-605-9788-65-6

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2024 - 2025

Project Fair Program

02 June 2025

10:30 - 10:45	Opening Speeches
10:45 - 11:30	Group Project Presentations
11:30 - 11:45	Alp Mercan Project Awards Ceremony
11:45 - 13:00	Project Demonstrations

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Preface

University-industry collaborations provide future engineers with a broad understanding of industry and business practices. Such collaborations also provide a platform for students to demonstrate creative design solutions to important problems encountered by industry. We provide this learning opportunity with a two-semester sequence of design courses for senior-level students. This year, 14 groups, each consisting of five to six students, were provided with design projects from leading industrial organizations. Projects were selected so that students could leverage their undergraduate studies to design a product needed in today's world. Projects were also selected to bring out the students' creativity in both the design phase, which is completed in the first semester, and the embodiment phase normally completed in the second semester. At their final presentation sessions, the students are provided with a unique opportunity to present detailed design specifications of their products and the finished prototypes to the industrial sponsors.

We, as a department, are grateful to the academic and industrial mentors, instructors, and teaching assistants for the continuous guidance and advice they provided.

On behalf of the Mechanical Engineering Department, I would like to thank all those who have generously contributed their time and resources, which enabled tomorrow's engineers to gain invaluable experience during this process and demonstrate their capabilities.

İlker TEMİZER
Professor and Chair
Mechanical Engineering Department
Bilkent University

Our Profound Loss
Alp MERCAN
(BilMECH, 2024)

Alp Mercan lost his life in an act of valor during the fire disaster at Bolu Kartalkaya...

In his memory, the Department of Mechanical Engineering is presenting

Alp Mercan Special Project Awards

for the three most successful projects.

List of Contributors

Teaching and Administrative Staff

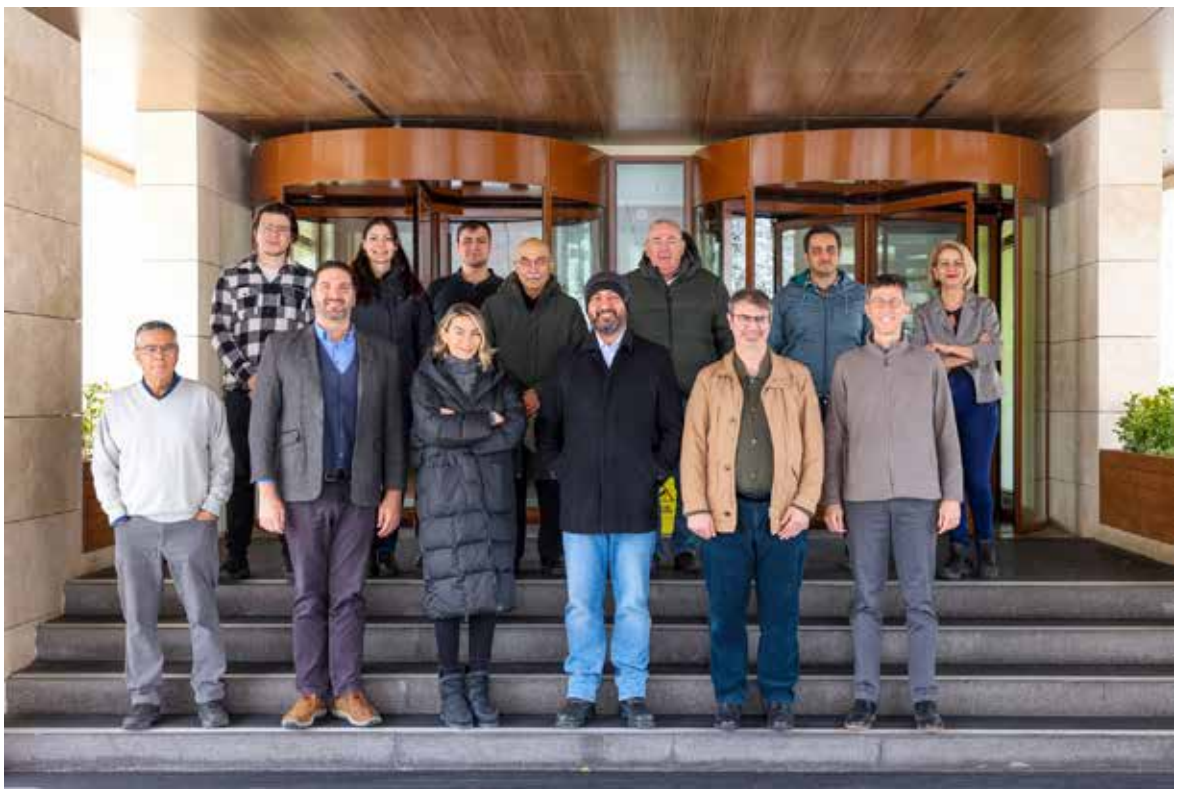
Prof. Barbaros Çetin, Ela Baycan
Doç. Dr. Müjdat Tohumcu, Yeşim Gülseren
Assoc. Prof. Yıldıray Yıldız

Over the years, this program has evolved into a vital bridge between academia and industry. A total of 138 projects have been successfully completed in collaboration with 27 industry partners, providing students with hands-on experience that extends far beyond the framework of a traditional course.

While these projects are formally conducted under ME 481-482 Mechanical Engineering Design I-II, the program itself is much more than just coursework. It serves as a true interface between student life and professional engineering practice, allowing students to engage in similar challenges they will face in their future careers. In essence, industry expertise is seamlessly integrated with the structured learning environment of a university course.

As instructors who have witnessed the program's growth and impact, we are highly satisfied with its progress. This success is the result of the collective efforts of many: students, industry mentors, teaching assistants, faculty members, and departmental staff. Their dedication and collaboration continue to shape this program into a meaningful and transformative experience for all involved.

Academic and Administrative Staff



Special Appreciation Message for the 10th Anniversary of "Bilkent University Mechanical Engineering Department Industry-Supported Graduation Projects"

Dear Mechanical Engineering Students,

I sincerely congratulate all the students who are celebrating their graduation this year. Over the past ten years, our Mechanical Engineering Department has accomplished many successful projects, each brought to life through your dedication, hard work, and technical expertise.

Throughout this journey, we have been honoured to guide you in mechanical projects, ensuring that theoretical knowledge is seamlessly integrated with practical application. We have experienced together that engineering is not only about calculations and design but also about understanding and mastering the production process.

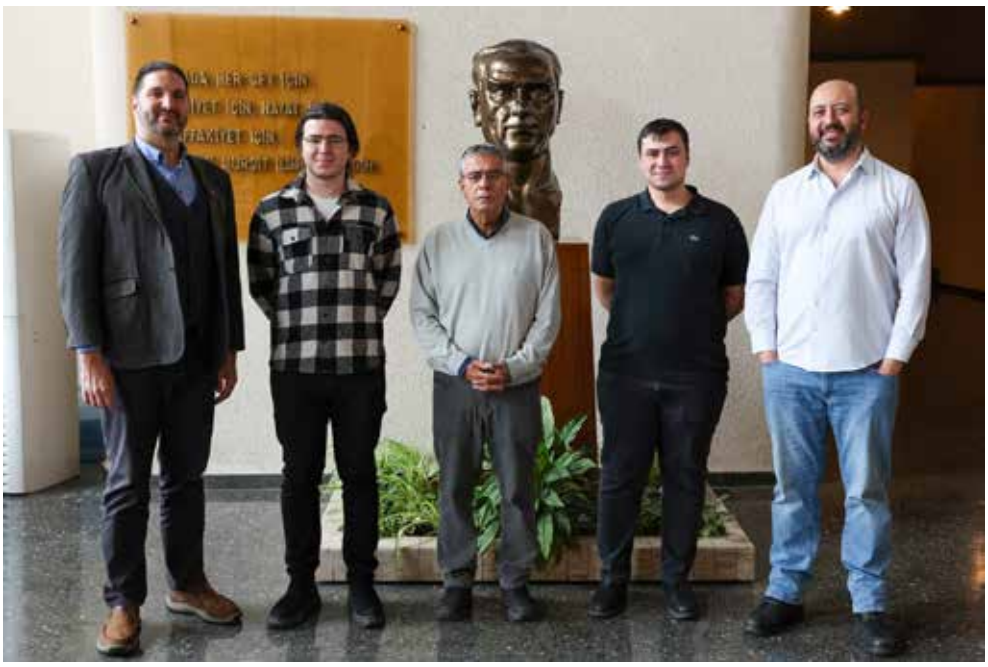
At this point, I would like to extend my special thanks to our esteemed workshop technician, Mr. Şakir Duman. With his expertise and meticulous approach, he played a crucial role in bringing your projects to fruition. His guidance in the workshop has helped you appreciate the importance of disciplined work, attention to detail, and high-quality production—skills that will be invaluable in your professional careers.

As you embark on your next journey, I am confident that the education and experience you have gained here will serve as a strong foundation for your future endeavours. I wish you all great success in your careers and look forward to seeing the remarkable projects you will accomplish.

Wishing you all the best in your future endeavours.

Dr. Şakir BAYTAROĞLU
Mechanical Engineering Department
Bilkent University

Teaching Staff



Instructors:

Prof. Barbaros Çetin

Doç. Dr. Müjdat Tohumcu

Assoc. Prof. Yıldıray Yıldız

Assistants:

Altar Sertpoyraz

Ege Özkan

Yiğit Yaman

Kerem Dülger

H. Dilara USLU
B.Sc. 2016, M.Sc. 2018

Lead Mechanical Design Eng.
ASELSAN

After graduating from Bilkent University's Mechanical Engineering Department in 2016, I pursued a Master's Degree. In addition to my research responsibilities, I undertook teaching assistant duties for three years in Mechanical Engineering Design I-II courses. These capstone courses required student groups to execute industry-based projects under the joint supervision of industrial and academic partners. These courses provided future engineers with the opportunity to identify engineering requirements, apply engineering standards, and utilize analysis software, while also enabling them to collaborate closely with industry leaders which is an invaluable preparation for professional life. As a coordinating assistant, I gained significant experience in mentoring senior students, delegating tasks based on their strengths and interests, and assessing group performance fairly—all of which greatly enhanced my leadership abilities. Moreover, helping others, motivating students, and serving as a role model were particularly rewarding aspects that contributed to my personal development. The skills I acquired during that period continue to shape my professional approach today. Over the past few years, I have been working as a Lead Mechanical Design Engineer at ASELSAN, where I specialize in developing electromechanical packaging solutions for a range of communication products including broadband radios, antennas, and datalink devices designed for aerospace, ground, and marine platforms. My responsibilities encompass the design, prototyping, integration, and testing of the mechanical components that enable these devices to operate effectively in demanding environments. Mechanical engineering is an ever-evolving discipline, especially with the rapid advancements in artificial intelligence, robotics, and advanced materials. For the pioneering engineers of the future, I emphasize the importance of curiosity and a genuine passion for innovation. Staying updated on the latest technological developments, coupled with practical experience in workshops, internships, and hands-on projects, will undoubtedly distinguish aspiring engineers in their careers.

Between 2020 and 2024, during my PhD studies, I had the privilege of contributing to the senior-year Mechanical Design Projects as a Coordinator Teaching Assistant. This course offers students a unique opportunity to collaborate with industry partners, tackle real engineering challenges, and apply their knowledge to practical, high-impact projects.

My transition from academia to industry clearly showed me the value of hands-on learning and real-world problem-solving, which are fundamental to this course. The experience, students gain here, is invaluable in preparing them for professional challenges. For me, it remains an unforgettable experience to see how future engineers push the boundaries of design and innovation.

Ayten Gülce BAYRAM (ÖZGÜR)
Ph.D. 2024

Global Technology Development Eng.
P&G (Germany)

Celebrating a Decade:
Alumni Journeys

2024 Graduates

2023 Graduates

2022 Graduates

2020 Graduates

2019 Graduates

2018 Graduates

2017 Graduates

2016 Graduates

Ece ÖZELÇİ
B.Sc. 2016
Thermal-Mechanical Engineer
CORINTIS

I'm Ece, an alumnus of Bilkent University's Department of Mechanical Engineering, graduated in 2016. For our senior design project, our team focused on design, analysis, prototyping and preliminary tests of an air bearing to be integrated into a gimbal mechanism for a high G-force application. This project, along with several other group projects during my time at Bilkent, provided me with an invaluable array of technical and interpersonal skills. I learned not only about engineering principles and practical prototyping but also about effective teamwork and the importance of meetings stakeholder expectations. After graduating, I pursued a master's degree in mechanical engineering at EPFL, where I later continued my academic journey by earning a PhD in robotics. During my doctoral studies,I developed a robotic microsurgery platform primarily intended for life-science applications, engaging in highly interdisciplinary research that I found both challenging and rewarding. Currently, I work as a Thermal-Mechanical Engineer at CORINTIS, a dynamic startup. My professional experience here reminds me of my senior design project days at Bilkent, particularly the emphasis on collaboration and interaction among team members. While a PhD often involves working independently with occasional collaborations, the industry-oriented experience of my undergraduate projects has been instrumental in preparing me for today's fast-paced work environments. I cherish my time as an undergraduate student and remain proud to be a graduate of Bilkent Mechanical Engineering.

I graduated from Mechanical Engineering Department in 2017. I have also obtained my MS degree with Prof. Ozcan in the same department and moved to United States for my PhD studies. Currently, I am working at TESLA as a Senior Controls Engineer. In my senior year, our group developed an electro-mechanical clutch system as our graduation project. I remember that we worked very hard and felt tired with all the final year classes, projects and excitement of graduation. In return, the knowledge and skills I gained in my graduation projects such as collaborative work, detail planning, and time management contributed greatly to my later career. Besides increasing my competence in process management, it made me more resilient for working in high paced environments. On the other hand, the network I made during the project played a very important role in excelling my career. When I look back, I can also see how much fun I had at the same time. That's why my advice is to appreciate and cherish these moments, you will see its outcomes in upcoming years one way or another. I wish success to everyone who will graduate.

Furkan GÜÇ
B.Sc. 2017, M.Sc. 2020
Senior Controls Engineer
TESLA

Ayla WATSUJI
B.Sc. 2018
R&D Engineer
ANYbotics

I am Ayla Watsuji, graduated from Bilkent University's Mechanical Engineering Department in 2018. I completed my master's degree at ETH Zürich in 2020. Since then, I've been working as a mechanical engineer in the R&D department of ANYbotics, developing quadruped robots for industrial inspection. The courses and projects at Bilkent, my research at the Miniature Robotics Lab, and my involvement in the Mechanical Engineering Society (MES) played a crucial role in shaping my career. In MES, we worked on a two-wheeled personal vehicle and a wall-climbing robot, gaining both theoretical and practical knowledge. My senior design project and work on flexible sensors provided valuable hands-on experience. In 2017–2018, our team completed the RoughTerrain Advancing Hexapod Surveillance Robot project with support from ROKETSAN. Starting from scratch and building a functional prototype helped me realize my passion for robotic design. Later, when applying to ETH's Robotic Systems Lab, I showed them our senior project video—which helped me land the opportunity. Back in my second year, I had seen a video from this lab and dreamed of working on their quadruped robot. Today, I'm one of the engineers developing its new versions.

Bilkent taught us how to work systematically and ethically—skills I now apply every day. I hope that my fellow recent graduates have also taken advantage of opportunities to engage in the fields they are passionate about. For those who have not yet decided on their career path, I want to say: you will come across many opportunities to explore don't hesitate to try them. Each experience will provide you with different perspectives, and eventually, you will reach the point you aim for. Bilkent has given us so much, but I believe the most important thing was learning to work systematically and ethically. Thanks to this, I am confident that wherever we go, we will continue to produce high-quality work.

I am Sehmuz Ali Subay, and I graduated in 2019. My graduation project was a semi-autonomous reconnaissance vehicle. It was a challenging project as we strived for optimal performance to enhance its autonomous capabilities. The system included an environment awareness algorithmusing a LIDAR sensor and a stereo camera, a navigation system to determine the current locationand destination, and a path planning algorithm to avoid collisions. We worked hard to overcome the challenges we faced throughout the project. The knowledge and experience I gained continue to benefit me in my professional life, even in seemingly unrelated areas. While working at Arçelik, I developed an algorithm in Python for designing 3D pipes. My inspiration for this came from the path planning algorithm I developed during my graduation project. In path planning, the goal is to avoid collisions and select the optimal route based on certain criteria. Similarly, in 3D pipe design, the pipe must connect a given start and end point while ensuring it does not collide with other solid components. The design process also involves iterative optimization criteria, much like in path planning.

Şehmuz Ali SUBAY
B.Sc. 2019
System Design Engineer
ASELSAN

Currently, I work as a system design engineer at ASELSAN, specializing in electro-optical systems. I am responsible for all technical aspects of the project, including integrating our electro-optical system into a crawler platform to enhance its environmental awareness capabilities. The system utilizes multiple cameras for target tracking, designating, and providing precise location information. The camera and navigation tasks in this system were areas that I explored with great interest during my graduation project. In conclusion, the lessons you learn from your graduation projects will always contribute to your professional life. Therefore, I highly recommend taking the time to develop yourself during these projects.

Deniz DOST
B.Sc. 2020
Mechanical Engineer
ROKETSAN

I'm a 2020 graduate. Our graduation project was to design and manufacture a semi-autonomous drone capable of detecting a missing child. Thanks to my teammates and the project's technical aspects, it was quite an enjoyable and a valuable experience. We were looking forward to the project fair to showcase our work, but unfortunately, due to the COVID outbreak in the middle of the second phase, we were deprived of this great opportunity. The industrial graduation projects are great at providing insights into how to manage and complete phases of an engineering project with various stakeholders. The standout takeaways, from a handful, offered are teamwork along with managing and presenting your work effectively. Being involved in an engineering project coming to life equipped me with a skill set that has been priceless in my journey after graduation. After Bilkent, I began working and soon after pursued a master's degree at the University of Michigan. Currently, I work at ROKETSAN. Both in the industry and in graduate school, I've come to appreciate how well our distinct curriculum prepared us for larger-scale projects. Quite often, I notice its impact on my perspective, approach and understanding of engineering challenges. It's been amazing to witness these projects become more exciting each year, driven by dedication of the students, faculty, and industrial partners. I believe the next decade will bring even more remarkable and challenging projects, with future engineers continuing to push boundaries and showcase their talent and innovation.

I'm Elif Özçelik, a 2021 graduate of Bilkent University Mechanical Engineering. Wow, time has flown by, it feels like just yesterday! To put it briefly, I am working in the field I studied. At the same time, I am a welding engineer and completed my master's degree in supply chain management at Politecnico di Milano. Although these fields may seem unrelated, my goal has always been to work in production and operations while also gaining knowledge in social and managerial processes. And that's exactly what happened. Today, while manufacturing sheet metal products in our family business, I can't think of a single skill I've developed that I haven't put to use. On this journey I have followed, my university has played one of the biggest roles in shaping my vision and mission. Bilkent Mechanical Engineering provides a great environment where we can see and push our limits while moving forward with the right people. From my first-year common courses to my graduation project, the program has always been professional, supportive, and highly instructive. One of its most effective aspects is its emphasis on both theory and practice.

Elif ÖZÇELİK
B.Sc. 2021
Technical Commercial Eng.
Metalif A.Ş.

For our senior design project, my team and I worked with Ford OTOSAN to develop a mechanical system that protects an electric vehicle's battery from impacts. Throughout the process, our professors, experienced alumni, and the company we collaborated with all dedicated their time and support to us. At every stage—research, analysis, documentation, and presentation—we encountered numerous challenges, overcame them, and learned countless valuable lessons. However, considering how well we communicated and how successfully we executed our project remotely, I believe it's clear that we had a strong foundation and took the right steps. In conclusion, I have truly loved my university, my department, my professors, my friends, and so many other things about Bilkent. I continue to love and appreciate them all. I feel deeply grateful to everyone who made this experience so meaningful for me. Proud to be a graduate of Bilkent Mechanical Engineering!

Şeymanur AL
B.Sc. 2022,
M.Sc 2024
PhD Researcher
Eindhoven Uni. Tech.

Looking back, my graduation project was one of the most valuable experiences of my academic journey. I had the opportunity to work with ROKETSAN, designing a quick-coupling system that enables missile fuel tanks to be filled without leakage. While it was a deeply technical challenge, the project was about much more than engineering—it was about teamwork, problem-solving, and learning how to collaborate with industry professionals. That foundation continues to influence my work today. I am now a PhD researcher at Eindhoven University of Technology in the Operations, Planning, Accounting, and Control Group, working on the Next Generation Autonomous Factory Project. This initiative, involving more than 20 companies, aims to strengthen the Netherlands' position in high-tech equipment manufacturing by advancing automation and achieving error-free production. The same principles I learned during my graduation project—technical excellence combined with industry collaboration—are what drive my current research. For students preparing for their own graduation projects, my advice is simple: embrace the experience fully. It's not just about completing a technical task—it's about developing skills that will set you apart in your future career. Whether in research or industry, the ability to communicate, collaborate, and think critically will be just as valuable as the technical expertise you gain.

I'm Sefkan Can Demir, a graduate of Bilkent ME, Class of '23. I am currently employed as an Electro-Optical System Engineer at ASELSAN, working in the Microelectronics & Electro-Optics Systems Business Sector. Alongside my professional career, I am pursuing my graduate studies at METU ME. At the end of my undergraduate studies, like every other ME student, I had to select a suitable group and a relevant graduation project. Our group chose ASELSAN's REHIS Business Sector's project: "Design and Analysis of a Multi-Point Locking Mechanism for an Airtight Access Door." The existing system caused delays since each locking mechanism had to be engaged separately, increasing maintenance time and slowing emergency access. To solve this, we developed a multi-point locking mechanism that streamlines the process, enhancing both efficiency and operational readiness. As a fellow graduate, I can confidently say that the Bilkent ME Graduation Project Program provides an excellent simulation of professional life.

Sefkan Can DEMİR
B.Sc. 2023
Electro-Optical System Eng.
ASELSAN

As a System Engineer, I must acknowledge that—from conducting literature reviews to evaluating alternative system designs, and from preliminary design reviews to critical design reviews—this program ensures that Bilkent ME graduates are well-prepared to take part in every stage of an industrial project. Even though budget-related issues may arise with companies in projects, Bilkent stands behind its students and supports them in financial matters. To all prospective alumni, be patient and ready to tackle any challenge. Professional life may seem like uncharted territory, but you will soon realize that Bilkent has already equipped you for it.

Ege ÖZKAN
B.Sc. 2024

M.Sc. Student
Bilkent University

For a brief introduction, I'm Ege Özkan, a Bilkent Mechanical Engineering graduate currently pursuing my master's degree in the same department. As someone who has gone through the same journey, to design and develop a mobile and easy-to-use sheet metal bending machine for METEKSAN SAVUNMA with my group, I can relate to the difficult challenges students face with and effert they spend to overcome those challenges. Regarding to that I would like to share a few words with my fellow undergraduate friends who are working on their graduation projects. First and foremost, I want to express my gratitude to all students who have worked tirelessly on their projects. I know how demanding this process can be. Some may see the graduation project as just another mandatory course; which, in a way, it is. However, beyond that, it offers one of the most valuable real-world engineering experiences, allowing students to apply everything they have learned throughout their studies. It is a bridge between academia and industry, preparing students for the challenges ahead. Graduating from Bilkent's Mechanical Engineering program is no small feat, and I sincerely congratulate all students who have successfully overcome the obstacles along the way. But graduation is not just an end, it is also the beginning of a new chapter, one where continuous learning and self-improvement become even more important. My advice to new graduates is to pursue their passions, embrace challenges, and never stop growing. As a final message, I wish you all success, fulfillment, and resilience in your future endeavors. May you find joy and purpose in everything you do.

Dr. Burcu DÖNMEZ

Director, Cruise Missile System
ROKETSAN

My name is Burcu DÖNMEZ, and I serve as the Director of the Cruise Missile Systems at ROKETSAN. I have been working in different organizations within our defense industry since 2002. My background is in Mechanical Engineering, but I have continued my journey in a multidisciplinary team, involving almost all branches of engineering, starting with mechatronic design. My relationship with Bilkent Mechanical Engineering started between 2012-2014, during which I taught mechatronics and mechanical dynamics courses. In 2015, I became one of the first technical sponsors of Bilkent ME graduation projects. In the early years, I had the opportunity to be more closely involved with graduation projects, and over time, I have always supported the spread and corporate engagement of these projects at ROKETSAN. During the difficult period of 2021-2022 caused by the pandemic, Professors Müjdat, Yıldıray, and I collaborated on finding ways to transition graduation projects to online platforms and developed effective solutions. Technical support we provided under our corporate identity, we have always approached the projects we manage as a long-term and mutual interview process. This approach has transformed the graduation projects into a mission that has brought many freshengineers to ROKETSAN over the years. I make it a point to follow the projects every year and participate in graduation fairs. Seeing the increase in the quality of the projects and the rise in student motivation truly makes me happy.I believe that, through this platform, we will continue to encounter very successful projects and talented engineering candidates in the future.

For the past decade, the collaboration between Bilkent University's Mechanical Engineering Department and Roketsan has been an invaluable bridge between academia and industry. Through the Industrial Graduation Projects, we have witnessed the power of knowledge, innovation, and dedication come together to shape you, the engineers of tomorrow. At ROKETSAN, we firmly believe in the significance of these projects—not only as a learning opportunity but also as a platform for young engineers to apply their skills to real-world challenges. Your journey through these projects has been a testament to the potential and talent that will drive the future of engineering. We take great pride in having contributed to this initiative, offering mentorship, resources, and expertise to support your growth. Dear graduating students, as you step into your professional careers, we encourage you to embrace challenges, stay curious, and continuously seek to improve. The world, especially our country, needs engineers who are not only technically proficient but also visionary and adaptable. We trust that the strong foundation you have built through these projects will empower you to excel in your future endeavors, and we hope it will inspire you to contribute to our country's advancement. We look forward to many more years of collaboration with Bilkent University, fostering new generations of engineers ready to make a difference. Congratulations on your achievements, and may your careers be filled with success and innovation.

Dr. Zeynep ALPASLAN

Leader, Academic Development & Learning Unit
ROKETSAN Academy Directorate

Uğur SUSUZ

Mechanical Design Manager
METEKSAN Savunma

Being the Mechanical Design Manager of METEKSAN Savunma, I am proud to support graduation projects for mechanical engineering students. Our involvement allows us to share our professional experience helping students transition from academic theory to tangible applications. It's rewarding for us to see them grow as they work on practical solutions to real world problems. As METEKSAN Savunma, we actively guide students to the creation of innovative and usable products, while also gaining fresh insights that benefit our ownwork. Witnessing students transform theoretical concepts into functional products for the first time is an achievement that enriches both their development and our role as their mentors. This collaboration is an invaluable experience for both the students and our team. By working on relevant engineering challenges, we support students in turning ideas into solid solutions, orientating with knowledge exchange and hands-on experience in the field of mechanical engineering. As they embark on their professional careers, we look forward to becoming new colleagues. I wish all the students continued success and I will be excited to see their growth and achievements as they advance in the engineering world.

10 Years of Bilkent Mechanical Engineering Capstone Projects– A Personal Reflection

It's amazing to see the Industry-Supported Capstone Projects at Bilkent University's Mechanical Engineering Department celebrating its 10th year! Over the years, I've had the privilege of being part of this journey, working with students to help them develop their teamwork and problem-solving abilities. One of the things I love most about this program is how it bridges the gap between university and real-world challenges. Seeing students grow throughout the process—learning to collaborate, communicate, and tackle complex problems —has been incredibly rewarding.Through the seminars I've given on team dynamics, my goal has always been to equip participants with the skills they'll need beyond just engineering expertise. To all the graduating students: Keep learning, stay adaptable, and don't underestimate the power of teamwork and communication. Engineering isn't just about technical know-how; it's also about working with people, leading with vision, and being resilient in the face of challenges. I can't wait to see where your careers take you! Happy 10th anniversary to this wonderful program.

Serdar BİLECEN

Vice President
KEYS CONSULTING

Onur DÜZGÖREN

Senior Mechanical Engineer
ROKETSAN

Greetings, I am a mechanical engineer with expertise in designing high-precision electromechanical systems in ROKETSAN. Throughout my 12-year career, I have been involved in not only designing these systems but also manufacturing every single part of them. Besides, testing and qualifying the design has been significant section of my job. Last year, I was honored to be part of the jury for mechanical engineering final projects at Bilkent University. It was exciting experience for me to listen the details of innovative solutions presented and offer constructive feedback. In addition, it was inspiring to witness the admirable effort that bright engineer candidates put forth. It means a lot to me to share my experience and knowledge about Design for Manufacturing and Assembly principles and I hope to guide them in production stage of their projects. I extend my best wishes to all the students involved. It is a great opportunity to apply everything you've learned over the past four years,learn how to manage your time and see the great contribution of effective communication with your group members. I wish you success in your professional career.

I am currently working as the R&D Director in the Dishwasher Division at BEKO. With nearly 20 years of experience in R&D and product development, I believe that the Capstone Project Program offers students a valuable opportunity to connect with the industry and work on real engineering problems.

The most important advice on my side to new graduates is to focus not only on improving their technical knowledge but also on developing their problem-solving skills and ability to work in teams. Being open to continuous learning and development will help them make a difference in their careers.

Dr. Önder BALİOĞLU

R&D Director,Dishwasher Div.
BEKO

Nejat ULUSAL

Founder, ULUSAL Makina

I am Nejat Ulusal, founder of an engineering company established in 2006. We specialize in designing and manufacturing custom mechanical systems tailored to customer needs. In recent years, we have also been providing solutions in intralogistics systems and autonomous mobile robots. The İ.D. Bilkent University Mechanical Engineering Graduation Project Program has always stood out to me as an excellent initiative. I believe that collaborating with industrial companies significantly increases the motivation of the students that results in hard work and ultimately producing remarkable results. I want my new colleagues to trust in themselves.The high-quality education they have received, combined with their ability to use technological tools, bring out their potential to become pioneers in the technical field of the country . I encourage them to strive for excellence rather than settling for mediocrity. Success comes through continuous effort. I am proud to have supported this program and to witness the success of young engineers emerging from it. I look forward to see graduates contributing to the industry.

Deniz DALLIÖZ

B.Sc. 2024

TUSAŞ

Deniz graduated from Bilkent University with a degree in Mechanical Engineering in 2020 and worked at BEKO for over three years, specializing in quality systems and reliability. She is now pursuing her career in civil aviation quality systems at TUSAŞ. She has been participating in the ME489/582 Fundamentals of Design for Reliability Engineering course to demonstrate system/component reliability analyses, present industry applications, and support term project ideas since 2020. She believes that our graduate projects—and our engineering program as a whole—equip us with skills in self-investigation, problem-solving, multidisciplinary&analytic thinking, and broad perspectives. To new graduates, she advises staying open to multidisciplinary thinking, understanding interactions, looking at the bigger picture, and also developing personal leadership skills—some of key expectations in today's professional world. She also reminds them about the importance of balancing upcoming work life with personal life.

This Year's Industry Supported Graduation Projects

Bilkent Üniversitesi
Makine Mühendisliği Bölümü

TEPE EMLAK

Waste Vending Machine and Software Integration Project

Trash Vendicoots (G01)

Academic Advisor : Prof. Dr. Barbaros Çetin
Industrial Advisor : Akif Karakoyun
Teaching Assistant : Altar Sertpoyraz

ABSTRACT

Currently, at Bilkent Center, a property of Tepe Real Estate Investment, visitors manually separate waste bottles in different bins which is prone to errors in waste separation [1]. This project involves creating an advanced reverse vending machine (RVM) equipped with AI technology to automatically separate glass, plastic and metal waste bottles. A modular cabin is designed with everything included in itself to accomplish the operation from start to end. Design and manufacturing is bound to predetermined constraints including both electrical and mechanical. Conveyor with levelling arms, pneumatic piston for compression, separator and waste bins are main units in this machine. The project proposes more compact and all in one way of recycling.

Problem Definition

Bilkent Center, as a lifestyle hub that transforms shopping into a pleasant and comfortable experience, has made a difference in the retail sector. As the first shopping center in Turkey to hold the "ISO 14064-1 Carbon Emissions Certificate", Bilkent Center also carries the titles of Ankara's first "Accessibility Certified" [1] and "Green Check-Green Control Certified" Green Shopping Center. Additionally, Bilkent Center participates in the zero-waste (Sıfır Atık) program [2].

Figure 1: Commonly Used Manual Waste Bins [3]

Currently, waste separation at Bilkent Center is done manually by visitors, and while waste is sorted, it is still transported to a recycling facility in a single mixed bag. However, as zero-waste program standards become stricter each year, Bilkent Center aims to be the first mall in Ankara to introduce reverse vending machines [4].

Figure 2: Commercial RVM [5]

The reverse vending machine (RVM) begins operation when waste is inserted. Sensors then detect key physical properties such as shape, size, dielectric constant, and weight.

This data is processed using AI-based detection algorithms and image recognition to accurately identify the material type. Once classified, the item is transferred via a conveyor system to the appropriate waste bin; plastic, glass, or metal. This automated process ensures precise sorting, reduces human error, and enhances the overall efficiency of recycling.

The RVM must identify and sort 500ml PET bottles, 200ml glass bottles, and 330ml aluminum cans using barcode scanning and AI-based image recognition. It should compact PET and aluminum items, sterilize entries with UV light, and reject containers with liquids. The system must alert users when bins reach 80% capacity and prevent fraud or unsafe usage. It must also include grounding, fire suppression, and safety features like obstruction detection and secure camera placement.

The machine must have a metal exterior, withstand a 500N impact, and fit within a 1000×1000×1000 mm space (±20%). The upper section will handle entry and sorting, while the lower stores separated waste in three bins. A 10.1-inch screen will provide user feedback, and an emergency stop button must be included. The compaction system may use a crusher or shredder and must meet dimensional and durability standards.

[1] “Anasayfa,” Bilkent Center, https://www.bilkentcenter.com.tr/.
[2] “Ana Sayfa - Sıfır Atık,” Sıfır Atık, https://sifiratik.gov.tr/.
[3] Quickwasters, “Importance of recycling bins.” [Online]. Available: https://www.quickwasters.co.uk/importance-of-recycling-bins/. [Accessed: Oct. 8, 2024].
[4] Bilkent holding, https://www.bilkentholding.com.tr/en/bilkent-holding-in-briefly.
[5] TOMRA, “TOMRA T70 Single reverse vending machine,” 2024. [Online]. Available: https://www.tomra.com/en/reverse-vending/our-offering/reverse-vending-machines/tomra-t70-single. [Accessed: Oct. 8, 2024].

Design

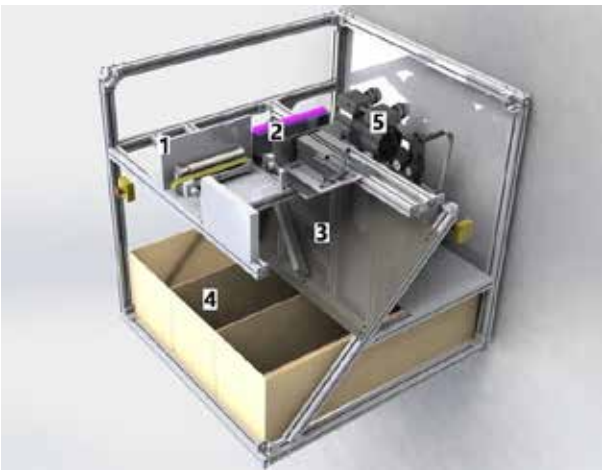


Figure 3 : 3D Model of the System

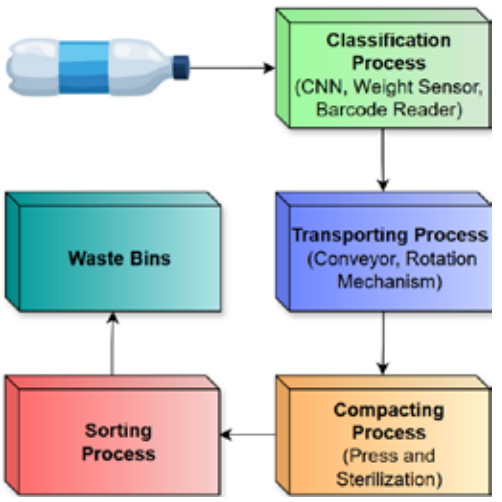


Figure 4 : Process Diagram of Waste Vending Machine

The machine consists of four subsystems. Bottles are taken in by the front cover into the classifying subsystem and moved by a conveyor system (1); where, CNN algorithm, load cells and barcode scanner work simultaneously to analyze bottle. If data is not matched or liquid present in them, bottles will be rejected. Then bottles will be transported into compacting mechanism (2), which uses a pneumatic press (5) to reduce bottle size. After compacting, separator (3) will allocate bottles to their separate bins (4).

All operation stops if anything other than bottle is detected by IR sensors at the entrance. The conveyor is driven by a DC motor. Servo motors are controlled by using the PCA9685 servo driver but some necessary functions were developed independently. An open-source HX711 library was used to read data from the load cells. GM67 barcode reader is used to determine product type via barcodes. The necessary functions were developed independently. The CNN model is trained on top of the VGG-19 architecture to fine-tune it for detection of bottles.

Outcomes

The reverse vending machine is an interdisciplinary project combining mechanical, mechatronics, electrical, and software design, supported by coursework in machine learning and programming. Scheduled for the 2024–2025 academic year, the project involves:

- Literature research
- Setting the requirements and the constraints of the machine with Tepe Real Estate Investment
- Preliminary and Computer-Aided Design (CAD) of subsystems, with engineering analyses for:
  - Static and Explicit Dynamics
  - Numerical Methods for Simulations and Radiation Analysis for the UV-Light
  - Mechatronic and Electrical components
  - Machine Elements Selection
  - Machine Learning Algorithm
- Safety Analysis & Risk Analysis
- Setting the manufacturing and assembly, system testing, system design verification and validation
- Manufacturing the final product

Industrial Advisor

G01: Akif KARAKOYUN

Bilkent Üniversitesi
Makine Mühendisliği Bölümü

roketsan

Design and Production of a Small-Scale Rocket Launch Hold-Down and Release Mechanism

Thrust ME (G02)

Fatih Göktuğ Kayan	Kazım Janberk Baştuğ	Selena Şahin	Sude Karataş	Ahmet Nuri Kirişci	Deniz Kaplan

Academic Advisor : Assoc. Prof. Dr. Onur Özcan
Industrial Advisor : Erdal Günay
Dr. Özgür Hastürk
Teaching Assistant : Yiğit Yaman

ABSTRACT

This project involves the comprehensive design, simulation, and prototyping of a small-scale Hold Down Release Mechanism (HDRM) tailored for model rocket launch systems. The HDRM is engineered to secure a launch vehicle measuring 1 meter in diameter and 1.5 meters in height, restraining it during ignition until stable thrust conditions are confirmed. The mechanism employs three hydraulically actuated arms, evenly distributed around the rocket, which securely lock the vehicle in place during the ignition phase. Once stability is achieved, and verified in real-time using a pressure sensor integrated into the hydraulic cylinders, the system initiates a synchronized release, completed within 100 milliseconds, ensuring minimal delay and fuel loss with limit switch sensors. To achieve high precision in timing and motion, the hydraulic actuation is coordinated, ensuring near-simultaneous disengagement across all arms. The mechanism is designed to withstand axial forces and lateral moments up to 20 kN during hold-down while incorporating safety redundancies to prevent post-release mechanical interference with the rocket. Emphasis is placed on reusability, structural robustness, and ease of manufacturing, making the solution both safe and economically viable.

Problem Definition

The liquid-fuelled launch vehicle propulsion systems cannot reach stable thrust immediately after the ignition command and require a mechanism to hold the vehicle until it reaches the stable thrust. Proper design of such systems presents the utmost importance since launch vehicle failures often stem from instabilities encountered during the initial moments of engine ignition, where thrust is unsteady and dynamic loads can cause misalignment or premature lift-off. These instabilities pose significant risks—not only to mission success, but also to surrounding infrastructure, payload integrity, and personnel safety. Even minor deviations in launch timing or rocket orientation during this critical phase can lead to catastrophic consequences, including mission aborts, structural damage, or total vehicle loss. Consequently, precision and control in the early launch sequence are of paramount importance.

Figure 1: ROKETSAN Micro Satellite Launch System [1].

To mitigate these risks, rockets are typically held in place by ground support mechanisms until their engines produce stable thrust, defined as a thrust force within ±1% of the target value. This project aims to develop a small-scale Hold Down Release Mechanism (HDRM) that replicates this process on a model launch platform. The HDRM must securely restrain a 1-meter diameter, 1.5-meter tall dummy rocket and release it with minimal delay once thrust stability is confirmed.

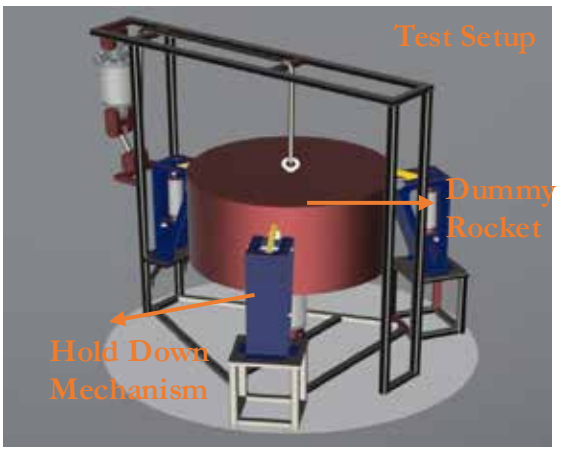


Figure 2: Hold Down Release and Test Setup Mechanism.

In addition, the mechanism must respond rapidly to the ignition command: no more than 200 milliseconds can elapse between the firing signal and the release of the first arm. This strict constraint is essential to prevent unnecessary fuel consumption and mechanical stress from prolonged hold-down conditions.

The system employs three hydraulic hold-down arms, symmetrically spaced at 120 degrees, which engage with structural docking features on the rocket body. These arms must sustain a combined axial and moment load of 20 kN for at least 10 seconds to simulate real launch conditions. Once the rocket reaches stable thrust, monitored by pressure sensors embedded in the hydraulic system, a synchronized release is triggered. All three arms must fully disengage within 100 milliseconds, ensuring a balanced lift-off without tipping or asymmetry.

The HDRM is designed to be non-explosive, hydraulically actuated, and fully reusable, meeting the demanding timing and force requirements of launch operations while prioritizing safety, precision, and efficiency.

[1] Roketsan, "Micro Satellite Launch System," [Online]. Available: https://www.roketsan.com.tr/tr/urunler/mikro-uydu-firlatma-sistemi. [Accessed: Apr. 15, 2025].

Design

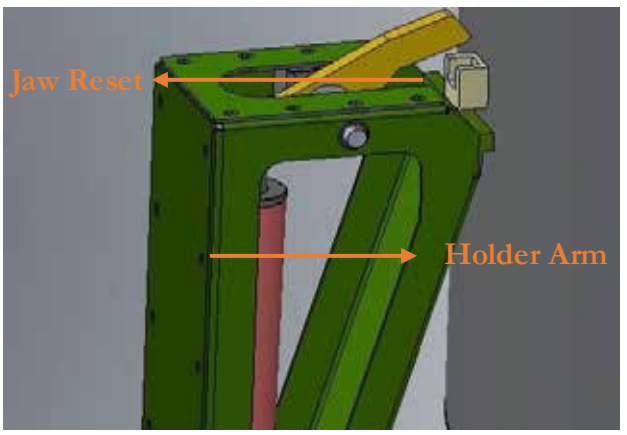


Figure 3 : Holder Arm Mechanism

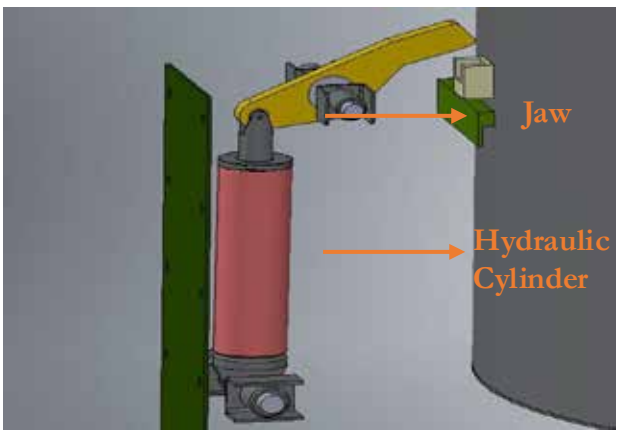


Figure 4 : Jaw and Hydraulic Cylinder Mechanism

The mechanism comprises three hold-down arms symmetrically placed at 120-degree intervals around the rocket's circumference. Each arm features a hydraulic locking unit that engages a securing arm that clamps onto the rocket. The system utilizes a pressure sensor connected directly to the hydraulic line to monitor thrust build-up in real-time.
When the thrust exceeds a pre-defined stability threshold, the pressure sensor sends a signal to the hydraulic control valve, activating cylinders to disengage the arms.

To ensure physical confirmation of full retraction, limit switches are installed at the base of each securing arm. These provide feedback to the controller, verifying that all arms have successfully disengaged. All hydraulic components, including valves (directional control, relief, poppet), sensors, pump, accumulator, and the control unit, are mounted on a compact base frame that provides mechanical support and ease of integration within a launch platform environment.

Outcomes

This system is a mechanical design project that combines the mechanical engineering knowledge acquired in dynamics, thermo-fluids, and mechatronics courses. It is done in several steps through the 2024-2025 academic year given below:

- Literature research
- Determination of sub-systems according to requirements provided by ROKETSAN
- Engineering analysis including:
  - Hydraulic System Modelling
  - Structural Analysis
  - Kinematic and Dynamic Analysis
  - Topology Optimization
  - Multi-body Dynamics Analysis
- CAD Drawings
- Test-Setup Design
- Planning of Manufacturing Processes, Assembly, Design Verification, and Testing of the System

This Project was funded by TUBİTAK 2209-B

G02: Erdal GÜNAY

As part of the "Small Scale Launch Vehicle Hold-Down and Release Mechanism" project, I had the opportunity to mentor students, guiding them through the fundamental principles of release/separation systems used in launch vehicle ground support equipment. With my area of interest in kinematic and dynamic analysis, as well as hydropneumatic systems, I helped them bridge the gap between theoretical knowledge and practical application. From the very beginning, their eagerness to learn and their determination to tackle complex engineering problems were truly inspiring. They approached every challenge with curiosity and a willingness to push their understanding further. Throughout the project, we worked together to analyze the structural integrity and dynamic behavior of the mechanism. I introduced them to computational tools such as FluidSim and Matlab, demonstrating how to perform simulations and interpret results effectively. By providing hands-on guidance, I ensured they developed a strong understanding of system performance under real-world conditions. My goal was not only to teach technical knowledge but also to encourage critical thinking and problem-solving. By challenging them with real engineering scenarios, I helped them gain confidence in their abilities and understand the complexities of designing reliable mechanical systems. Their curiosity and enthusiasm made the experience even more rewarding, reinforcing the importance of mentorship in engineering education. Working with these students reinforced my belief in the power of mentorship and the potential of newly graduated engineers from Bilkent University. Their dedication, innovative thinking, and enthusiasm for learning made this experience incredibly fulfilling. I have no doubt that they will continue to excel in their engineering journeys, and I am grateful to have played a role in their growth. I would like to thank Bilkent University for providing this opportunity.

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roketsan

High Precision Two-Axis Gimbal for Eliminating the Bias Errors of IMU

Zenithron Dynamics (G03)

Academic Advisor : Assoc. Prof. Onur Özcan
Industrial Advisor : Dr. Caner Gençoğlu
Teaching Assistant : Yiğit Yaman

ABSTRACT

Navigation systems in military aircraft often rely on GPS, which can be vulnerable to jamming in combat zones. In such scenarios, an Inertial Measurement Unit (IMU) is used as an alternative to ensure continued navigation. This project aims to develop and manufacture a high-precision two-axis gimbal system to eliminate bias errors of IMU and enhance its reliability by providing accurate multi-axis freedom through pitch and yaw rotation. The gimbal is specifically designed for integration into the Lockheed C-130 Hercules cargo aircraft and operates under strict dimensional and performance constraints. The main challenges of the project include mitigating vibration effects caused by the aircraft's operational environment and achieving high positional accuracy. With this project, a more reliable and robust solution is proposed for navigation in GPS-denied environment.

Problem Definition

Gimbal systems are widely used in defense and aerospace applications for stabilization and sensor alignment. In GPS-denied environments, aircraft such as the Lockheed C-130 Hercules rely heavily on Inertial Measurement Units (IMUs) to maintain navigation accuracy. IMU is an electronic measurement device that calculates the forces it experiences, angular rate of that force and position with gyroscopes. However, IMUs are susceptible to accumulating random bias errors over time, which can compromise the performance and safety of navigation systems. To address this issue, a gimbal system capable of precise yaw and pitch rotations is required to periodically reorient the IMU and suppress error drift.

Figure 1: Inertial Measurement Unit Turna-TM [1]

This project aims to design and manufacture a high-precision two-axis gimbal to be integrated with an IMU and mounted inside a C-130 aircraft. The primary objective is to maintain accurate sensor orientation under high-vibration conditions and ensure long-term bias error mitigation through controlled motion. The system must operate within strict constraints, including a maximum size of 150 mm^3 for the payload and a total weight below 20 kg, while offering ±180° of freedom in both yaw and pitch axes. Angular error must be limited to ±1°, and the system should reach its desired rotation speed of 5 RPM within 5 seconds.

The gimbal must also be robust enough to withstand the harsh vibrational environment inside a military aircraft, as specified by MIL-STD-810G standards. Mechanical design considerations include maximizing the natural frequency of the frame to avoid resonance, ensuring ease of manufacturability, and enabling smooth rotation through the use of high-precision stepper motors, bearings, and damping components. The manufacturing stages are finalized with respect to ISO 2768 standards. Additionally, the system will feature a control algorithm to reduce positional drift, with real-time feedback and synchronization using IEEE 1588-2008 time protocols.

Figure 2: Aircraft Route Correction

The project aims to develop a functional prototype of a two-axis gimbal based on the technical specifications provided by Roketsan, enabling its use in future defense-related projects and collaborative research with Bilkent University and serve as a testbed for further development.

[1] Roketsan, "Roketsan - Navigation Systems," Roketsan, Sep. 08, 2021. https://www.roketsan.com.tr/en/products/navigation-systems.

Design

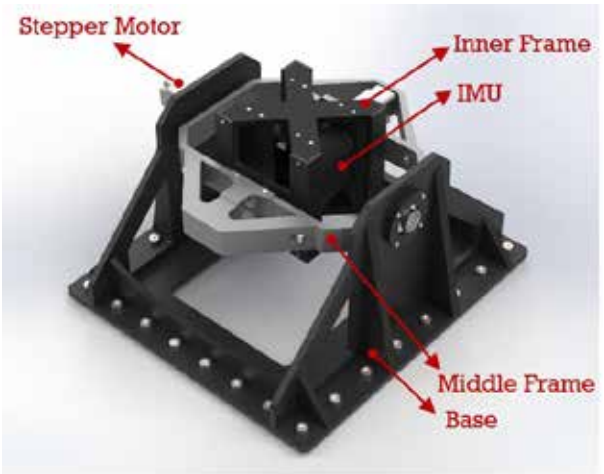

Figure 3 : 3D Model of The System

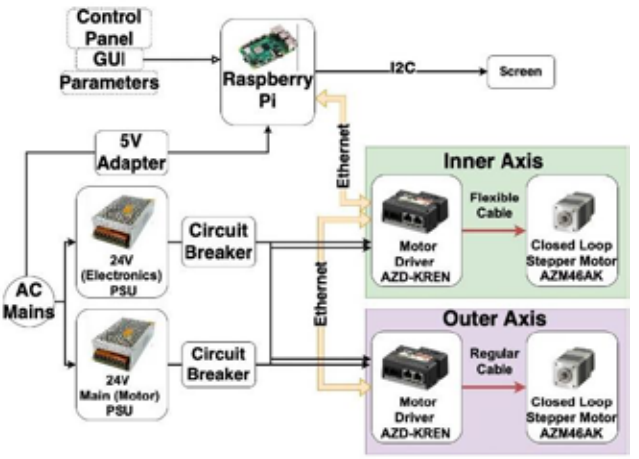

Figure 4 : Electrical Scheme

The gimbal system is composed of three main structural layers: an inner, middle, and outer frame, all constructed from 6061 aluminum for optimal strength-to-weight ratio. The design prioritizes ease of assembly, vibration resistance, and precise motion. Bearings and shafts are integrated to enable smooth yaw and pitch motion, while special grooves in the structure ensure safe cable routing without restricting rotation.

The electrical system consists of a Raspberry Pi 5, high precision closed-loop stepper motors, drivers, and encoders. The system is powered by two 24V 5A power supplies, one dedicated to motors and the other to control electronics with protective circuit breakers. A custom GUI allows real-time control and monitoring. The system ensures accurate positioning through continuous encoder feedback and high-speed communication between components.

Outcomes

This system is a mechanical design project that combines the mechanical engineering knowledge acquired at dynamics, control systems and mechatronics courses. It is done in several steps through the 2019-2020 academic year given as below:

- Literature research
- Determination of sub-systems according to requirements provided by ROKETSAN
- Engineering analysis including:
  - 1DOF/6 DOF System modeling
  - Control system construction and analysis
  - Mathematical modeling
  - Inverse kinematics analysis
  - Frequency response analysis
- CAD drawings
- Safety Analysis
- Planning of manufacturing processes, assembly, design verification and testing of the system

Bilkent Üniversitesi
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METEKSAN SAVUNMA

Design of an Automatic Leveling Platform

HighLeveled (G04)

Onat Alkın Can | **Mehmet Ferhat Sever** | **Emre Bektaş** | **Muhammed Can Yılmaz** | **Ahmet Alperen Özbir**

Academic Advisor : Assoc. Prof. Dr. Yıldıray Yıldız
Industrial Advisor : Onur Berk Salcan
Teaching Assistant : Ege Özkan

ABSTRACT

The objective of this project is to design a compact automatic leveling platform capable of maintaining a precise horizontal orientation in dynamic environments. Conventional leveling platforms are often unsuitable for applications with strict spatial constraints and continuous motion disturbances. This project addresses the need for a space-efficient, accurate and adaptive platform. The proposed system utilizes a 3-RRS parallel manipulator driven by servo motors and equipped with an inertial measurement unit to enable real-time orientation correction with a leveling accuracy of 0.2°, under base misalignments up to 30°. The platform incorporates both classical PID and advanced Model Reference Adaptive Control strategies enhanced by sigma modification to maintain control stability under various signal inputs. Comprehensive structural analyses including static, modal and random vibration simulations have confirmed the system's reliability under operational stresses. The final design successfully manages to provide robust performance in harsh and vibration-prone environments.

Problem Definition

Leveling precision is a critical requirement in systems where high stability and alignment are necessary for proper functionality in dynamic environments. Traditional manual or bulky leveling systems are insufficient for compact and high-precision applications due to their volume, complexity and energy inefficiency. These limitations are particularly prominent in places where real-time compensation for platform inclination is required in the presence of disturbances such as vibration.

The targeted use case involves stabilization systems mounted on platforms where maintaining a stable orientation under external excitations is essential for operational accuracy. In such environments, any misalignment of the sensor platform can introduce significant errors in the system's measurement and targeting capabilities.

The proposed system addresses these issues by introducing a 3-RRS parallel manipulator configuration capable of three-axis active leveling. The design operates with input from an Inertial Measurement Unit (IMU), enabling the microcontroller to evaluate platform tilt and drive stepper actuators in real time to ensure alignment with a neutral reference plane. The platform is constrained to correct base misalignments up to 30°, while preserving leveling accuracy within 0.2°, under dynamic disturbances with frequencies up to 10 Hz, simulating wind gusts or mechanical movement. These capabilities are validated through detailed dynamic modeling, vibration testing and implementation of robust control strategies.

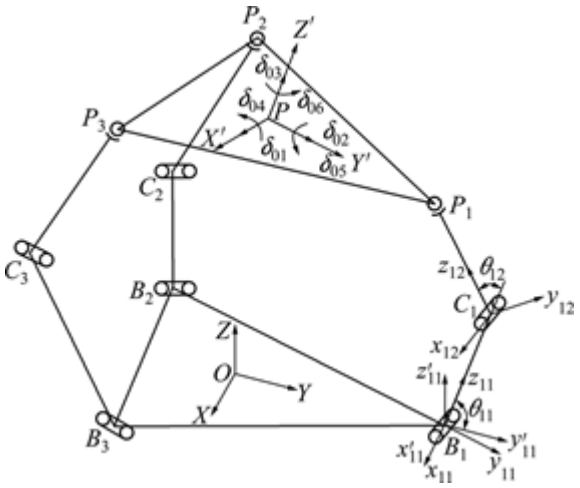

Figure 1: 3RRS Parallel Manipulator Kinematics [1]

Physical constraints, such as platform dimensions not exceeding 50×50×32.5 cm and a maximum supported payload of 25 kg, are critical to ensure the system's integration into restricted spaces. Additionally, to ensure the platform's viability in field conditions, compliance with MIL-STD-810G standards for vibration and shock has been mandated. The control architecture incorporates both classical Proportional Integral Derivative (PID) and Model Reference Adaptive Controller (MRAC) strategies, enhanced with sigma modification to ensure control parameter stability. Future works considered as AI-based model estimation through Long Short-Term Memory (LSTM) networks for predictive compensation and adaptive tuning.

This project aims to bridge the gap between traditional leveling mechanisms and the demands of compact, responsive and reliable leveling systems suited for modern defense and industrial applications.

[1] S. Liu, Z. Zhu, B. Zi, C. Liu, and Y. Yu, "Dynamics of 3-DOF spatial parallel manipulator with flexible links," in *Proc. 2010 Int. Conf. Mechanic Automation and Control Engineering (MACE)*, Wuhan, China, Jun. 2010, pp. 2327–2331, doi: 10.1109/MACE.2010.5535537.

Design

Figure 2 : 3D Model of the System

Finalized system is based on a 3-RRS parallel manipulator architecture, developed to enable precise and responsive three-axis leveling. It mainly consists of a base platform, three lower arms, three upper arms and a top platform. The system's operation begins with three stepper motors, each responsible for rotational movement of connected rod.

The control system including the drivers and Raspberry Pi microcomputer is mounted on the base platform, ensuring centralized signal and power distribution. To secure the motors in place, custom motor covers act as flanges and are fixed to the base structure, also serve to protect the motor assemblies from external environmental factors and mechanical impacts.

Outcomes

This project represents a comprehensive mechanical system design effort that integrates the theoretical and practical knowledge gained through coursework in dynamics, control systems, mechanical design and mechatronics. The project was executed throughout the 2024–2025 academic year in a sequence of well-structured phases. The major outcomes are as follows:

- Comprehensive literature review on automatic leveling systems and parallel manipulators
- Definition of system architecture and identification of subsystems based on requirements
- Structural integrity assessments:
  - Static structural analysis
  - Modal analysis to identify resonant modes
  - Random vibration and response spectrum analysis (MIL-STD-810G 514.6 and 516.6)
- Control design including:
  - Kinematic and dynamic modeling of the 3-RRS parallel manipulator
  - Linear and nonlinear control system design utilizing both PID and MRAC architectures
  - Stability and response analysis under varying load and disturbance profiles
  - System linearization and state-space modeling for control algorithm implementation
  - CAD modeling and digital twin construction in SolidWorks® and Simscape Multibody®
  - AI-augmented control strategy proposal using Long Short-Term Memory (LSTM) networks
- Bill of materials preparation, cost analysis and definition of manufacturing and assembly strategy
- Design for manufacturability assessment, including tolerance standards and component simplification for CNC, laser cutting, eloxal coating.

This Project was funded by TUBİTAK 2209-B

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HARP

Design and Production of an Thermoacoustic Refrigeration

CryoSonics (G05)

Can Önol Artun Alp Öztaş Ayşe Duru Çınar Ayda Önsoy Alp İskit Çağın Aydın

Academic Advisor : Prof. Barbaros Çetin
Industrial Advisor : Mehmet Yener

ABSTRACT

The Thermoacoustic Refrigerator project presents a tailored solution in sustainable cooling by transforming acoustic energy into refrigeration without conventional refrigerants or complex moving parts. A precision-controlled acoustic driver generates sound waves that, when directed into a carefully tuned resonator, stack, and heat exchanger, create a standing-wave pattern. This process establishes a thermal gradient that lowers temperatures by at least 5°C below ambient. Advanced simulation tools such as CFD and DeltaEC are used to optimize the system's geometric and material parameters to efficiently convert approximately 100 W of acoustic power into cooling performance. Key materials are ASA for the stack, POM for structural components, and aluminum for heat exchangers, which were chosen for their durability, precision, and minimal environmental impact. Innovative manufacturing methods such as CNC machining and EDM ensure the fine tolerances required, while adherence to international safety standards guarantees reliable operation. This project aims to explore the potential of a novel eco-friendly cooling concept, with the hope that it may contribute to the development of more sustainable refrigeration solutions in the future.

Problem Definition

Traditional refrigeration systems rely heavily on chemical refrigerants and intricate mechanical components, leading to energy inefficiencies, high maintenance, and environmental hazards. The use of toxic substances and complex machinery not only drives up costs and the risk of operational failures but also limits the adaptability of these systems in compact or environmentally sensitive applications.

The Thermoacoustic Refrigerator project offers a fundamentally different approach by employing acoustic energy for cooling. In this system, a precision-controlled acoustic driver produces sound waves that are directed into an innovative resonator, where a stable standing wave is established. This acoustic wave interacts with a carefully engineered stack and heat exchanger assembly to generate a thermal gradient that significantly reduces ambient temperatures. Achieving this effect demands exact control over the acoustic conditions, as even minor deviations can diminish the cooling efficiency.

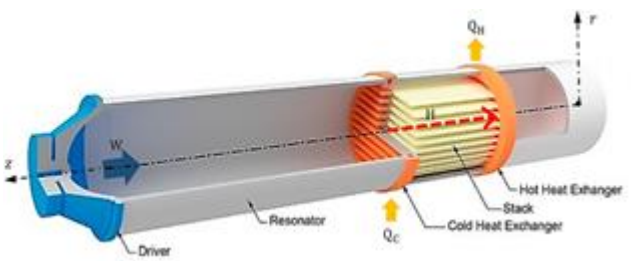

Figure 1: Thermoacoustic Refrigerator [1]

To overcome these challenges, advanced simulation tools such as Computational Fluid Dynamics (CFD) and DeltaEC are integrated into the design process.These tools help optimize the geometric and operational parameters of the resonator, stack, and heat exchanger, ensuring that the acoustic energy is effectively converted into a cooling potential. Maintaining a consistent standing wave and uniform energy distribution across the system is central to this effort, requiring meticulous tuning of every component—from the acoustic driver to the material interfaces.

Material selection is also critical. The project employs ASA for the stack due to its high manufacturing precision, polyoxymethylene (POM) for structural elements because of its durability and effective sealing, and aluminum for the heat exchangers to exploit its superior thermal conductivity. Advanced manufacturing methods, including CNC machining and wire electrical discharge machining (EDM), are utilized to meet the strict tolerances required for optimal performance. Through this comprehensive approach, the Thermoacoustic Refrigerator project aims to demonstrate a sustainable, low-maintenance alternative to conventional refrigeration methods, paving the way for next-generation cooling solutions.

[1] M. A. Ahmed, M. S. Uddin, M. T. Islam, and M. R. A. Beg, "Design and construction of a thermoacoustic refrigerator," *International Journal of Engineering Research and Technology (IJERT)*, vol. 10, no. 5, pp. 763–768, May 2021. [Online]. [Accessed: Apr. 11, 2025].

Design

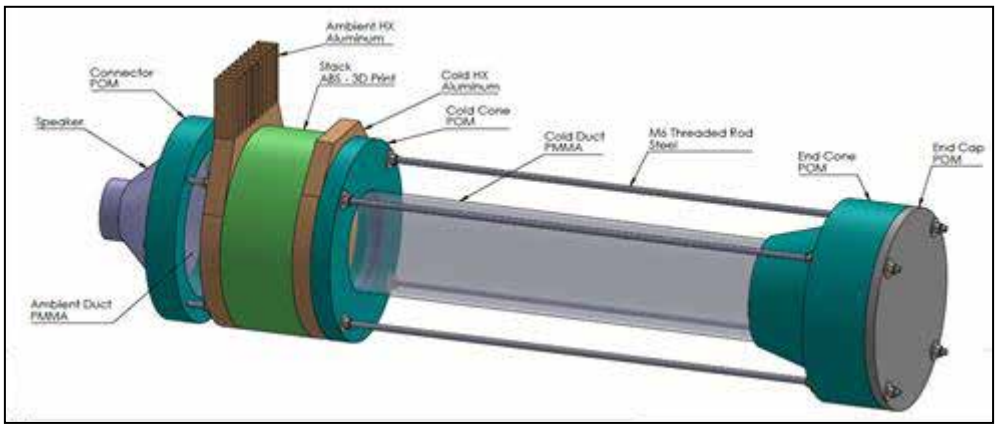

Figure 2 : Technical Design of the Thermoacoustic Refrigerator

The Thermoacoustic Refrigerator transforms acoustic energy into efficient cooling. A precision acoustic driver produces calibrated sound waves that are directed into a custom-designed resonator, where a stable standing wave creates a thermal gradient to drive the refrigeration cycle without conventional refrigerants or moving parts. Advanced simulations, including CFD and DeltaEC, optimize the geometry and operating parameters of the resonator, stack, and heat exchangers, efficiently converting around 100W of acoustic power into cooling.

The stack is fabricated from ASA for high precision, while structural components use POM for durability and leak-proof assembly, and aluminum is selected for its excellent thermal conductivity in the heat exchangers. High-precision manufacturing techniques, such as CNC machining and wire EDM, ensure that all components meet strict tolerances. This integrated design approach yields a sustainable, low-maintenance cooling solution poised to redefine refrigeration technology.

Outcomes

This system is a mechanical design project that combines the mechanical engineering knowledge acquired at thermofluidics and applied thermodynamics courses. It is done in several steps through the 2024-2025 academic year given as below:

- Conducted literature review on thermoacoustic refrigeration.
- Performed CFD and DeltaEC simulations to optimize resonator geometry, stack design, and heat exchangers.
- Selected materials (ASA, POM, aluminum) for thermal performance, durability, and leak-proof assembly.
- Used CNC and EDM machining for high precision and consistent component quality.
- Achieved ≥5°C cooling below ambient with ~100W of acoustic power.
- Validated an eco-friendly system without harmful refrigerants or complex mechanics.
- Built a foundation for future performance testing and real-world adaptation.

G05: Mehmet YENER

The collaboration between HARP, a leader in advanced cooling technologies, and Bilkent University, renowned for its cutting-edge research, opens up an exciting opportunity to explore thermoacoustic refrigeration—a promising, sustainable alternative to conventional cooling systems. This partnership could lead to breakthroughs in environmentally friendly, energy-efficient refrigeration solutions. Students at Bilkent University will gain hands-on experience working alongside HARP's engineers, designing, prototyping, and testing thermoacoustic refrigeration systems. This practical exposure not only enriches their academic journey but also equips them with the skills necessary for a successful career in innovative engineering fields. Bilkent University's theoretical knowledge in thermodynamics and acoustics, paired with HARP's industrial experience in applied cooling technologies, creates a powerful synergy. Together, they can advance thermoacoustic refrigeration systems from theoretical concepts to practical, scalable solutions, addressing real-world industry needs and market demands. This collaboration not only benefits students by providing them with practical, market-driven experience but also strengthens the ties between HARP and Bilkent University in their pursuit of innovation and sustainability in cooling Technologies.

Automized Sunshade

Suns N' Shade (G06)

Academic Advisor : Assoc. Prof. Dr. Yegan Erdem
Industrial Advisor : Gürkan Seven
Teaching Assistant : Ege Özkan

ABSTRACT

The scope of this project is to design and produce an adaptive sunshade system that can move according to the position of the sun in order to protect sensitive electronic systems from direct sunlight and environmental thermal stresses, thus enhancing their operational lifespan. The main goal of sun tracking mechanisms is to establish a balance between maximum shading performance and minimum energy consumption. The system developed in this direction has a foldable structure to adapt to environmental conditions and is designed to provide maximum shade area in sunny weather conditions and to take a compact form in night or cloudy weather conditions. The shade structure is manufactured from materials with high ultraviolet resistance, which do not undergo deformation in outdoor conditions, and is designed to be resistant to wind loads up to 90 km/h and precipitation conditions. The movable arms in the system are directed by a control algorithm that follows the position of the sun, thus preventing direct contact of sun rays with the devices. The solution proposed in the project is to develop a modular, easy-to-install, high-strength adaptive sunshade system that can operate underweight and geometry limitations.

Problem Definition

The reliability of electronic systems used in military operations is of vital importance for operational success. These systems are usually mounted on mast structures and are exposed to direct sunlight in open terrain. High heat from the sun reduces the performance of these sensitive electronic components and even causes permanent damage, jeopardizing the success of the missions. Existing solutions are generally static and are not resistant to variable weather conditions, especially strong winds. In addition, these systems offer limited opportunities in terms of energy efficiency and portability.

Current sun protection solutions, such as fixed and manually adjustable sunshades, are widely used due to their simplicity and low cost. However, they lack flexibility and compactness because they cannot be folded while they are not used. Unlike current solutions, this project introduces a durable, mobile, flexible and foldable electronic shading system for use in especially military fields in order to protect electronic systems on the mast and other mobile vehicles exposed to sunlight by adjusting the position of the sunshade and getting itself shut down before and after the operation. In this way, both energy and space savings are achieved and operational efficiency will be increased. Regarding the aim of the project, there are several requirements and constraints. The prototype should protect a box containing electronics whose dimensions are 45 cm X 60 cm X 30 cm from direct sunlight. The system should have at most 30 kg of mass.

The designed system has been strengthened according to engineering principles to withstand wind speeds of 90 km/h. Additionally, the maximum temperature of the electronic components of the system that are not exposed to direct sunlight is 55°C. If they are exposed to the sunlight, it should not exceed 71°C.

Figure 1: AI Generated Symbolic Representation of Automized Sunshade

In addition, the system is designed to automatically fold itself before and after the operation and to adjust its direction according to the position of the sun. Lightweight and UV-resistant composite materials were preferred in the system in order to ensure both durability and not to exceed the mass limit. Thanks to its modular and foldable structure, it offers fast installation and easy portability in different areas.

Design

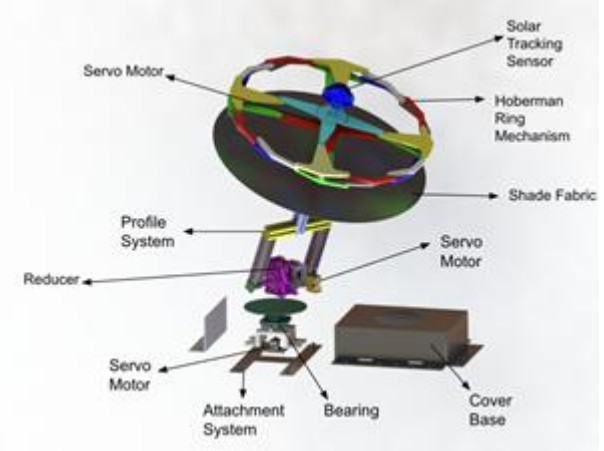

Figure 2: Exploded view of Hoberman Ring Mechanism

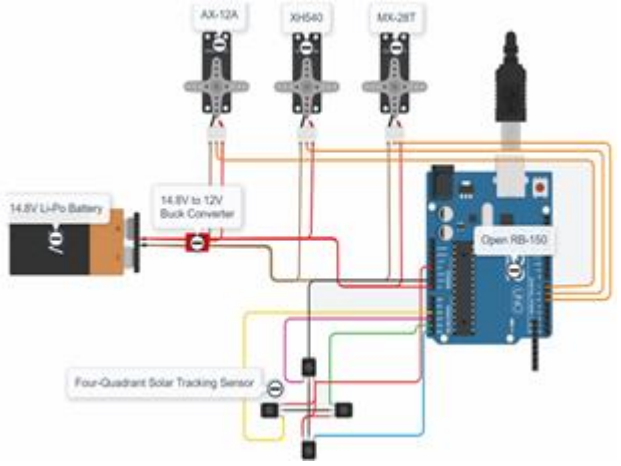

Figure 3 : Connections of Electronic Component

The design includes a shade fabric, a foldable Hoberman Ring mechanism, three servo motors, a sun-tracking sensor, and a reducer. Servo motors positioned in three different locations in the system the data received from the sun-tracking sensor and enable instant 360-degree tracking. AX-12 servo motor directly connected to the Hoberman Ring mechanism folds the system by changing its position, XH-540 servo connected to the reducer adjusts the elevation of the sunshade, the servo at the bottom provides azimuth motion for the whole system.

The Hoberman ring, which can be contracted thanks to its mechanism when there is no sun, provides space efficiency. Sun-tracking sensor and servo motors are controlled by OpenRB 150. The optimum voltage level for servo motors and OpenRB-150 is 12V, and for the sensor is 5V. The reducer located in the center provides self locking ability to the system under wind conditions and it increases the torque provided by the servo. In addition, two-sided sigma profile connections are resistant to high wind speeds and enable symmetrical movement. The system is mounted on the box.

Outcomes

This project is a comprehensive mechanical design study that integrates the knowledge gained from courses such as Mechanics and Materials, Dynamics and Control, and Mechatronics. It has been carried out in multiple phases throughout the 2024–2025 academic year, as detailed in the steps given below:

- Determination of constraints and requirements provided by Meteksan Savunma A.Ş.
- Literature research
- Preliminary and detailed design in SolidWorks
- Engineering analysis including:
  - Static analysis
  - Heat analysis
  - Dynamical analysis and torque calculations
  - Control system construction and analysis
- Safety and risk analysis
- Planning of manufacturing processes, assembly, design verification and testing of the system

This Project was funded by TUBİTAK 2209-B

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aselsan

Design of a Stirling heat pump with linear actuators

Termal Dalgalar (G07)

Ali Tunahan Tanrıöver | **Mehmet Yiğit Zaif** | **Ömer Tarık Mumcu** | **Yunus Selçuk**

Academic Advisor : Prof. Dr. Barbaros Çetin

ABSTRACT

This project presents the design, development, and partial manufacturing of an innovative Stirling-cycle heat pump that utilizes linear actuators for mechanical motion conversion. Aimed at providing a sustainable alternative to conventional vapor-compression systems, the design emphasizes reduced greenhouse gas emissions, quieter operation, and higher durability. The system comprises a custom piston-cylinder assembly and a ball screw-driven linear actuator to achieve the required motion and pressure characteristics, with an expected coefficient of performance (COP) of at least 4 and a cooling capacity of 2 kW. Standards such as ISO 3408-3, ISO 4393, ISO 3320, and ISO 1101 were adopted to guide precision manufacturing and ensure mechanical reliability. The project integrates sensors and programmable logic controllers for real-time monitoring and control, while also addressing potential challenges including vibrations, sealing integrity, and thermal modeling inaccuracies. Backed by funding from ASELSAN and Bilkent University, the system aims to offer a compact, efficient, and environmentally friendly solution for residential and industrial heating applications.

Problem Definition

While economic and technological advances have improved living conditions, they've also increased energy demand and environmental harm. The building sector is a major contributor, with households responsible for 20% of greenhouse gas emissions and 24% of energy use in the EU [1]. Heating and cooling systems are key culprits, often using inefficient appliances and harmful refrigerants.

Heat pumps offer an efficient alternative by transferring heat using minimal electrical or mechanical energy. Their performance is measured by the coefficient of performance (COP); for example, a COP of 3 means 1 kW of input yields 3 kW of heating. Overall, heat pumps provide an energy-efficient, low-emission solution for heating and cooling.

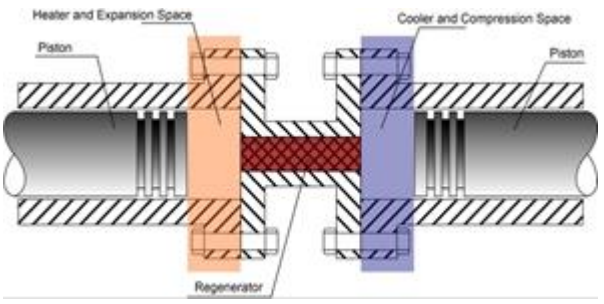

Figure 1: Alpha type Stirling machine.

While efficient, most heat pumps rely on vapor-compression cycles using high-GWP refrigerants, which harm the climate and ozone layer. The EU plans to phase out these gases by 2050, leading to a push for alternative technologies [2]. Heat pumps can also be noisy and require frequent maintenance, raising costs and reducing user comfort.

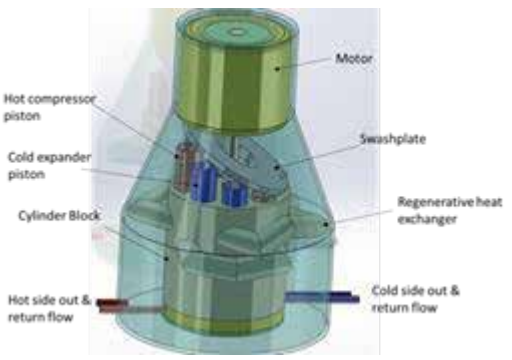

Figure 2: An example prototype of Stirling heat pump [3].

To address these issues, this project uses a Stirling cycle heat pump, which avoids high-GWP refrigerants and may offer quieter operation. The goal is to develop a sustainable, user-friendly heat pump suitable for residential and industrial use. The system will target a COP of at least 4 and a cooling capacity of 2 kW, tested within ±7°C of room temperature—benchmarks aligned with commercial standards.

This project applies several, including ISO 3408-3 for ball screws, ISO 4393 for piston stroke lengths, ISO 3320 for cylinder and piston rod dimensions, and ISO 1101 for geometric tolerancing. ISO 3408-3 helps guide the selection of ball screws by specifying load ratings, dimensions, and performance limits. ISO 4393 and ISO 3320 ensure the use of standardized, compatible components, simplifying design and replacement. ISO 1101 defines precise geometric requirements for form, orientation, and position—critical for features like piston alignment and sealing surfaces.

[1] "Greenhouse gas emission statistics - air emissions accounts."https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Greenhouse_gas_emission_statistics_-_air_emissions_accounts#Analysis_by_economic_activity.
[2] "Regulation (EU) 2024/573 of the European Parliament and of the Council of 7 February 2024 on fluorinated greenhouse gases, amending Directive (eu) 2019/1937 and repealing Regulation (eu) No 517/2014." https://eur-lex.europa.eu/eli/reg/2024/573/oj.
[3] "Near Isothermal Stirling Heat Pump," *Fluid Mechanics Ltd*, Nov. 28, 2020. https://www.fluidmechanics.co.uk/near-isothermal-stirling-heat-pump/.

Design

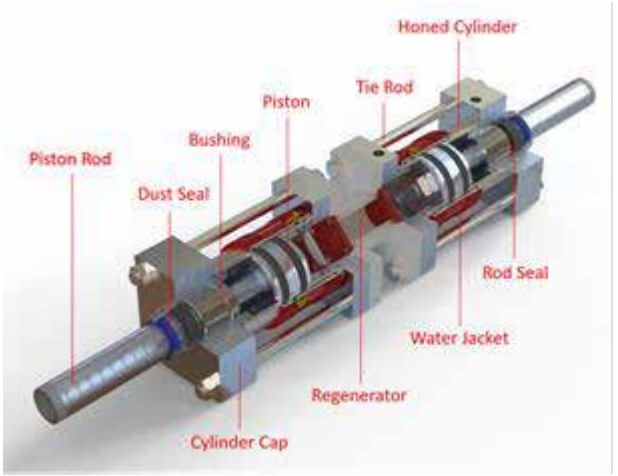

Figure 3 : Piston-Cylinder assembly.

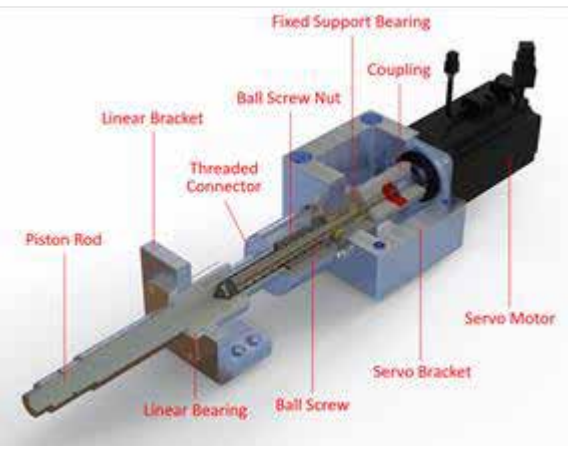

Figure 4 : Linear Actuator assembly.

The heat pump is designed in an alpha configuration, converting servo motor rotation into linear motion via a ball screw. The piston-cylinder assembly was designed using a custom pneumatic system, as standard parts couldn't meet the dimensional needs, especially for the water jacket. Sealing elements like U-rings and bushings were used to prevent leakage and reduce vibration. This design allows higher pressures with less servo force, and while it introduces some dead volume, calculations show it's a worthwhile trade-off.

The linear actuator was also designed for a simpler, more compact structure. It features an open design, supported by a linear bearing to maintain mechanical stability. The system combines two actuators with the piston-cylinder assembly on a base plate, with sensors feeding data to a PLC for control and performance analysis. This layout improves accessibility and assembly, making it well-suited for testing and demonstration.

Outcomes

This project has required the use of combined mechanical engineering information from previous academic years, mainly thermodynamics, manufacturing, and control systems. Throughout 2024-2025 academic year multiple planned steps were taken to assure timely production, which are namely:

- Literature research
- Defining requirements of the system through information acquired with literature research
- Engineering analysis including:
  - 1D thermodynamic analysis
  - Control system construction and analysis
  - Optimization using neural networks
  - Structural analysis
- CAD drawings
- Safety Analysis
- Planning of manufacturing processes, assembly, design verification and testing of the system

This Project was funded by TUBİTAK 2209-A

Industrial Advisor

G07:Cihan TURGUT

I hold a Bachelor of Science degree in Mechanical Engineering from Middle East Technical University and a Master of Science degree in Computational Mechanics from the Technical University of Munich (TUM), Germany. During my postgraduate studies and subsequent professional experience in Germany, I worked in both the automotive and aerospace industries, gaining interdisciplinary knowledge and hands-on expertise over a period of five years. For the past 15 years, I have been employed at ASELSAN, where I currently serve as the Manager of the Thermal Control Design and Mechanical Analysis Department. In this role, I lead multidisciplinary teams engaged in the design, simulation, and validation of advanced thermal management solutions for defense and aerospace applications. The Bilkent University Graduation Project initiative is a successful model of university–industry collaboration. It provides a structured platform through which students can engage with real-world engineering challenges, receive mentorship from industry professionals, and critically assess the practical implications of their design decisions. Graduation Projects not only fosters technical competency and systems-level thinking among students but also enhances their awareness of industry standards, workflows, and innovation strategies. By participating in such initiatives, students are better equipped to make informed decisions about their early career trajectories and to transition more effectively from academic environments into professional engineering roles.

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Design of an Experimental Setup for Reed Valve Force and Flow Coefficient Calculation

PRO-TESTERS (G08)

Academic Advisor : Prof. Dr. Barbaros Çetin
Industrial Advisor : Dr. Pouya Pashak,
Dr. Aamir Shahzad
Teaching Assistant : Altar Sertpoyraz

ABSTRACT

The aim of this project is to design and develop a customized experimental setup for the precise measurement of force and flow coefficients of reed valves used in hermetic reciprocating compressors. Accurate evaluation of these coefficients is essential for improving the performance and reliability of refrigeration systems, as they directly influence the refrigerant flow and the mechanical response of valve components. The proposed system seeks to address the current limitations in experimental validation, typically reliant on computational simulations, by providing a reliable, cost-effective, and compact platform for physical testing. The setup is designed to meet specific requirements including sensor integration, modularity for various valve geometries, data acquisition capabilities, and measurement accuracy within acceptable uncertainty bounds. Additionally, the project explores innovative techniques for displacement measurement, pressure control, and system modularity to ensure ease of manufacturing and maintenance. The final design incorporates a rigid frame, a custom test section, and a sensor-integrated two-axis positioning system, offering a versatile and robust solution for comprehensive analysis of reed valve dynamics as requested by Beko A.Ş.

Problem Definition

Hermetic reciprocating compressors rely on reed valves to regulate refrigerant flow, making their performance critical to overall efficiency. Due to their complex geometry, reed valves are prone to mechanical failure, and accurate determination of their flow and force coefficients is essential. However, these values are often estimated through simulations with limited experimental validation. To address this, the project aims to design and construct a modular experimental setup for Beko A.Ş., enabling precise, repeatable testing of reed valves using advanced sensors and a reliable data acquisition system.

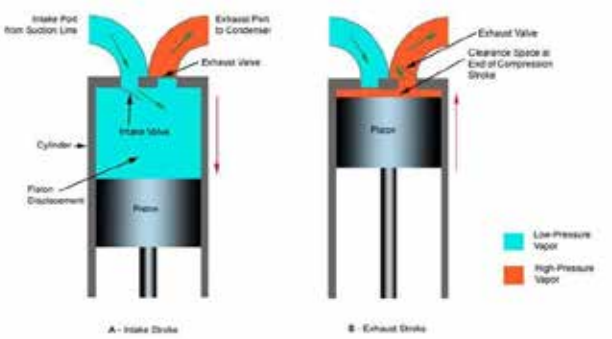


Figure 1: Intake (suction) and exhaust (discharge) stroke of a hermetic reciprocating compressor [1]

The system includes real-time measurements of pressure, temperature, flow rate, and valve tip displacement using a robust DAQ system operating at 50–100 Hz. A user-friendly interface and touchscreen display allow for real-time visualization and logging of all critical parameters. Measurement consistency and allowable uncertainty range of ±5% were taken into account during the design and validation phases to ensure the reliability of experimental outputs.

The test setup allows flexible mounting of various valve geometries (up to 60x50 mm), and features a 2-axis positioning system to support precise sensor alignment and tip displacement control. The airflow is supplied through a regulated direct pressure line, eliminating the need for an external tank. The design also incorporates sigma profiles for structural rigidity, reducing machining complexity while enhancing adjustability.

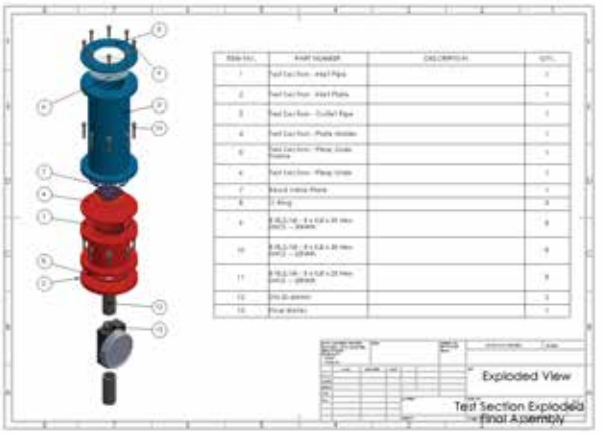


Figure 2: Exploded View of the Test Section

High-quality components like O-rings and helicoils ensure air-tight sealing and durability. The modular design allows easy sensor integration for future tests. This setup offers Beko a compact, versatile, and cost-effective platform to better understand reed valve behavior and enhance compressor performance.

[1] Berg Chilling Systems Inc., "Refrigeration Principles and how a Refrigeration System Works | Berg Chilling Systems," BergChilling Systems Inc., Aug. 25, 2020. https://berg-group.com/engineered-solutions/the-science-behind-refrigeration/

Design

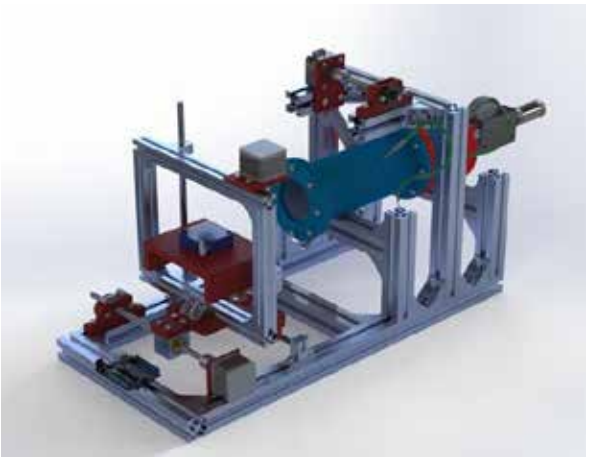


Figure 3: Rendered Image of the Setup

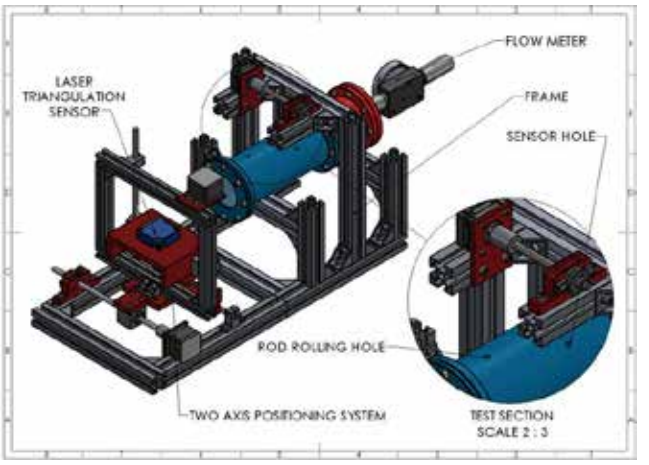


Figure 4: Technical Drawing of the Setup

The experimental setup is designed for the measurement of force and flow coefficients of reed valves used in hermetic reciprocating compressors. The system is composed of a test section, aluminum piping, and a modular frame constructed from sigma profiles to ensure maximum stability and ease of assembly. Temperature, pressure, displacement, and flow rate are measured using integrated sensors, while accurate alignment and data collection are ensured by a two-axis positioning system.

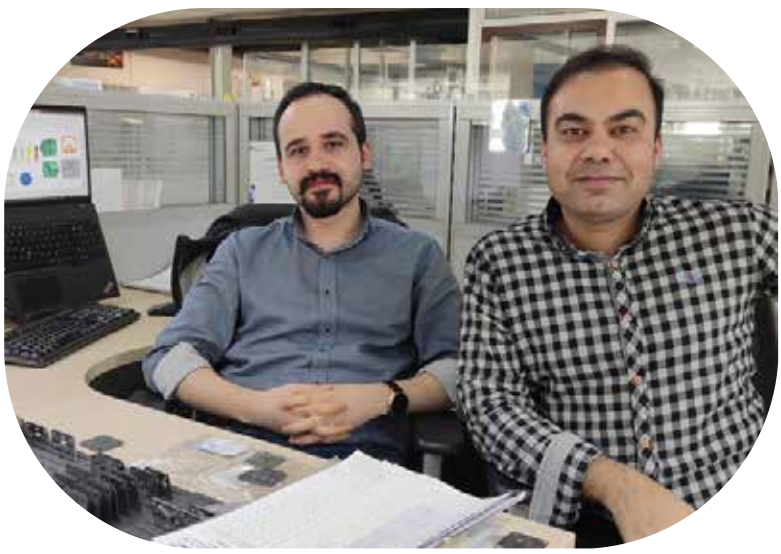
Advanced components such as O-rings and helicoils are used to ensure air-tight connections and long-term durability. The use of a monitor interface and real-time data acquisition system enables intuitive monitoring and control. CAD modeling and precise machining ensure all components are manufactured to meet performance and safety standards, ensuring the system's reliability and repeatability.

Outcomes

This project represents a complete mechanical engineering design process combining knowledge from fluid mechanics, sensor integration, instrumentation, and manufacturing. Carried out during the 2024–2025 academic year in collaboration with Beko A.Ş., the project includes the following phases:

- Conducting literature review and requirement analysis.
- Identifying subsystems based on engineering needs.
- Detailed design and analysis, including:
  - Designing the modular test section and piping system.
  - Building a two-axis sensor positioning system.
  - Developing a displacement mechanism for reed valves.
  - Integrating pressure, temperature, and flow sensors.
  - Designing the GUI and DAQ system for real-time control and logging.
  - Ensuring modularity for various valve plate geometries.
- Creating detailed CAD models and technical drawings.
- Manufacturing and assembling the full setup.
- Testing and validating measurement uncertainty range of ±5% for reed valve analysis.

G08: Aamir SHAHZAD & Pouya PASHAK



The household refrigerator compressor is the core part of the whole refrigeration system, and among all its more than 50 parts, the reed valves are particularly prone to failure due to their thin structure (0.076-0.250 mm). Precisely measuring the flow and force coefficients of these valves is critical for predicting mass flow rate and valve surface forces in thermodynamic models. For this purpose, researchers use Computational Fluid Dynamics (CFD) simulations due to their low cost and simplicity, there is a lack of experimental validation for these results. This project aims to bridge that gap by designing and developing an experimental setup to calculate these coefficients. Working with the Bilkent university students on this project has been a great experience. Their enthusiasm and fresh perspectives have contributed significantly to this research, while also allowing them to gain hands-on experience in experimental design and validation. Collaborating with them created a dynamic learning environment, enabling both knowledge transfer and innovation.

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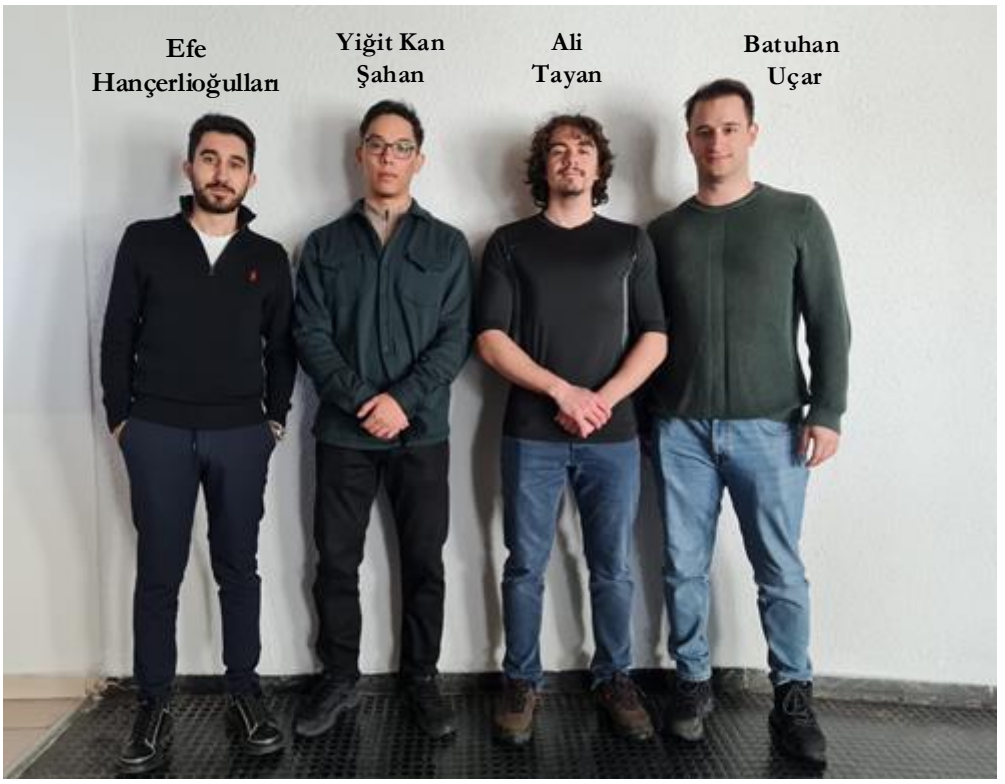
Design and Production of a Two-Step Hinge Mechanism For an Access Cover

Group 09 (G09)



Academic Advisor : Assoc. Prof. Dr. Ali Javili
Industrial Advisor : Mehmet Canberk Bacıkoğlu
Petek Ellialtıoğlu Danış
Teaching Assistant : Yiğit Yaman

ABSTRACT

The aim of this project is to design a compact and functional access cover mechanism for radar systems. In these systems, various electronic units are embedded inside the radar chassis, and access covers are used to enable assembly and disassembly of these units. In specific applications, some electronic units are mounted directly on the access cover and are connected with cables. The project aims to prevent cable damage during operation by enabling the access cover to first move linearly for 60 mm parallel to the ground, and then rotate 50 degrees around a vertical axis. The solution product is an electronically controlled two-step hinge mechanism that enables this specific motion sequence. Since the electronic components can be operated with high precision this type of an mechanism was chosen. The proposed solution of the project is to provide a motion-controlled access cover system that meets the specific functional, spatial, and structural requirements of the radar chassis.

Problem Definition

The development of two-step hinge mechanisms represents a critical evolution in mechanical design, particularly for applications requiring complex motion within constrained environments. Unlike traditional hinges, which facilitate simple pivoting around a fixed axis, two-step hinges are engineered to enable sequential motion, initially a linear displacement followed by rotational movement. This innovation is particularly beneficial in high-precision, compact systems found in aerospace, robotics, and defense sectors.

This project centers on designing and implementing a two-step hinge for the access cover of an electronic radar chassis, as specified by ASELSAN. The design not only addresses the spatial limitations of the chassis (290x250x105mm) but also enhances operational efficiency and component protection. The mechanism must allow the cover to slide linearly by 60 mm and then rotate 50 degrees, enabling controlled access while minimizing the risk of mechanical interference or component damage.

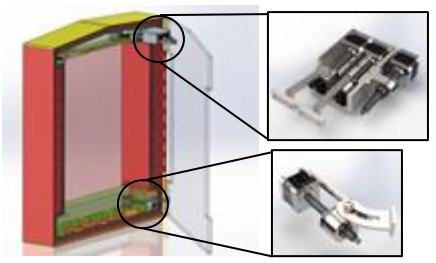


Figure 1: The Mechanism on The Provided Chassis

The primary engineering challenge lies in achieving high performance in limited space. Inadequate hinge design could compromise the safety and reliability of cable connections during maintenance. Therefore, this project integrates principles of ergonomics, safety, and structural integrity, supported by literature for functional design in restricted dimensions [1].

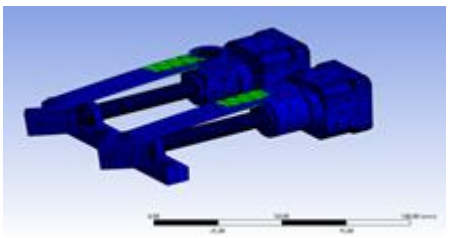


Figure 2: Closed Form Fatigue Analysis in ANSYS

Environmental resilience is validated against the military standards, MIL-STD-810H. Vibrational analysis is conducted under Procedure I (514.8) through ANSYS simulations, applying random vibration profiles to assess structural responses [2]. Shock resilience is tested using Method 516.8, simulating in-use impacts with transient structural analysis [3]. These procedures ensure that the hinge maintains mechanical stability during real-world operations.

Moreover, IP65 compliance is a key design target to protect internal radar components against dust and water ingress. This is simulated in ANSYS by applying internal pressures, helping identify and rectify potential leakage points prior to physical testing.

To guarantee manufacturability and quality, ISO 2768-1 general tolerances are applied, particularly crucial given the hinge's tight integration within the chassis [4]. Functional validation is carried out through dimensional inspection and assembly testing, ensuring smooth linear and rotational transitions with no alignment issues.

[1] Pahl, G., Beitz, W., Feldhusen, J., & Grote, K. (2007). Engineering design. In Springer eBooks. https://doi.org/10.1007/978-1-84628-319-2

[2] MIL-STD-810H-Method-514.8-vibration. (2019, August). cvgstrategy.com. https://cvgstrategy.com/wp-content/uploads/2019/08/MIL-STD-810H-Method-514.8-Vibration.pdf

[3] MIL-STD-810H-method-516.8-shock.(2019, August). cvgstrategy.com . https://cvgstrategy.com/wp-content/uploads/2019/08/MIL-STD-810H-Method-514.8-Vibration.pdf

[4] General Tolerances ISO 2768-1 Part 1"-, www.rpproto.com/wp-content/uploads/2021/05/General-Tolerances-ISO-2768.pdf

Design

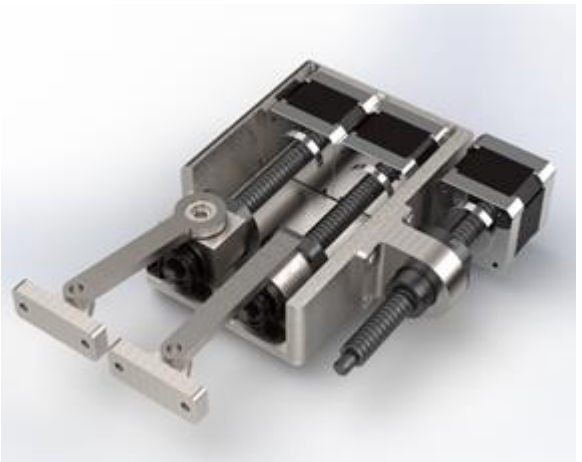


Figure 3 : 3D Model of the System

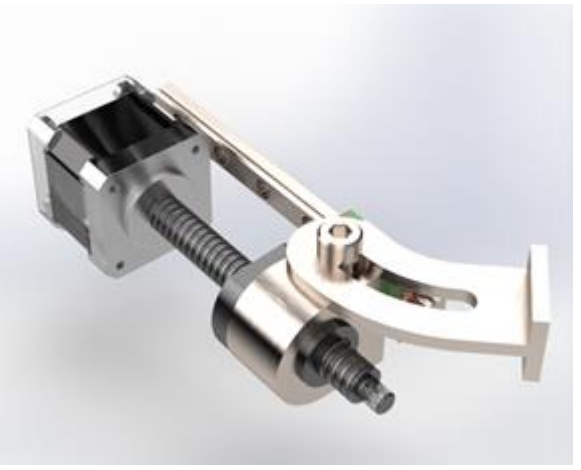


Figure 4 : 3D Model of the Secondary Mechanism

The system was finalized as a dual-motion mechanism composed of four parallel lead screws, each directly connected to the access cover through robust connection arms. These arms ensure synchronized motion and transmit forces effectively, supporting both linear and rotational movement modes. When the lead screws rotate in the same direction and at equal speed, the access cover moves linearly along guide rails mounted to the base. In contrast, rotational motion is achieved by driving the screws at different speeds.

The connection arms convert into a controlled angular displacement via a rotational coupling. Each lead screw is driven by a stepper motor controlled by an motor driver and an arduino. Pillow block bearings and a lead screw resting base ensure structural support, while ball screws enable manual operation with minimal friction. The system is enclosed in a protective case, housing all components securely and ensuring both precision and reliability during operation.

Outcomes

This system is a mechanical design project that integrates engineering principles from machine design, structural mechanics, and materials science. The project was conducted over the 2024–2025 academic year and followed a structured development process as outlined below:

- Literature research
- Requirement definition based on specifications provided by ASELSAN
- Engineering analysis including:
  - Kinematic analysis of the linear-to-rotational motion
  - Structural analysis for load capacity and vibration response
  - Finite Element Analysis (FEA) under MIL-STD-810H vibration and shock profiles
  - Environmental sealing and IP65 compliance evaluation
- CAD modeling and detailed mechanical drawings
- Tolerance and fit analysis in compliance with ISO 2768-1
- Simulation and validation of mechanical performance under operational conditions
- Planning and execution of manufacturing, assembly, and verification procedures

This Project was funded by TUBİTAK 2209-B

G09: Petek ELLİALTIOĞLU DANIŞ

I am Petek Ellialtıoğlu Danış, and I graduated from Bilkent University Mechanical Engineering Department in 2018. During my senior year, I started working at ASELSAN as a candidate engineer, which marked the beginning of my professional journey. I later completed my master's degree in the Solid Mechanics program at İTÜ Mechanical Engineering Department. Currently, I continue my career at ASELSAN as a lead mechanical design engineer. My work focuses on the design and R&D of mechanical systems for high-performance radar and antenna applications. This field requires a multidisciplinary approach, integrating structural integrity, thermal management, and electromagnetic compatibility. The strong engineering foundation I gained at Bilkent has been instrumental in tackling these challenges and contributing to the advancement of cutting-edge technologies. The Industrial Graduation Projects Fair, now celebrating its 10th year, serves as a valuable platform for students to showcase their technical capabilities and problem-solving skills while fostering collaboration between academia and industry professionals. I have had the privilege of participating in this fair as a student, an advisor, and an evaluator. This is my second time serving as an industrial advisor, guiding students through their final year projects while strengthening the connection between academia and industry. Bilkent University is renowned as one of the premier institutions in Türkiye for engineering education, offering a robust technical foundation and fostering a culture of innovation. Being part of this community is a privilege, and I encourage students to embrace every challenge, knowing that their experiences here will shape their future success.

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SPORTS INTERNATIONAL

Cleaning Drone for Solar Panels and Windows

SkyWasher (G10)

Academic Advisor : Assoc. Prof. Dr. Onur Özcan
Industrial Advisor : Hakan Öztürk
Teaching Assistant : Altar Sertpoyraz

ABSTRACT

This project centers on the design and development of a cleaning drone, specifically engineered for the maintenance of solar panels and building windows. Aimed at minimizing manual labor and improving cleaning efficiency in hard to reach locations, the drone is equipped to deliver pressurized water via a hose system while maintaining stable flight. The system is designed to operate under payload constraints and outdoor conditions, ensuring consistent performance without compromising maneuverability. In the design phase, significant emphasis has been placed on optimizing thrust to weight ratio, ensuring waterproofing of electrical components, and achieving structural durability using lightweight materials. With the integration of advanced control algorithms and real time telemetry, the drone is expected to deliver precision, reliability, and safety. As the project moves toward prototyping, efforts are concentrated on flight stability, cleaning effectiveness, and robust performance in real world environments.

Problem Definition

The rapid urbanization and increasing adoption of solar energy have created a critical need for efficient cleaning solutions for high rise windows and solar panels.

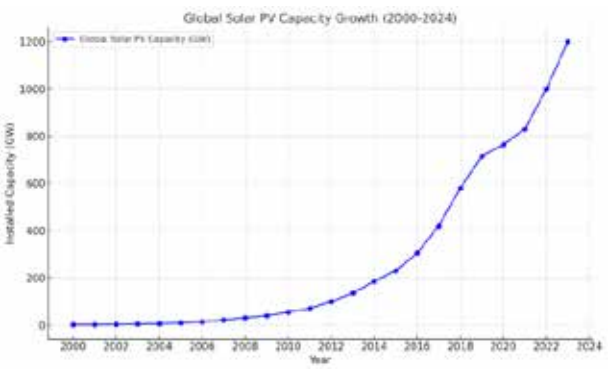

Figure 1: Installed capacity of solar panels between 2000-2024 [1]

Traditional methods, such as manual cleaning with scaffolding or lifts, are labor intensive, costly, and pose significant safety risks. Solar panels, in particular, suffer up to a 50% reduction in energy output when contaminated with dust or debris, yet their elevated or remote installations make manual cleaning impractical.

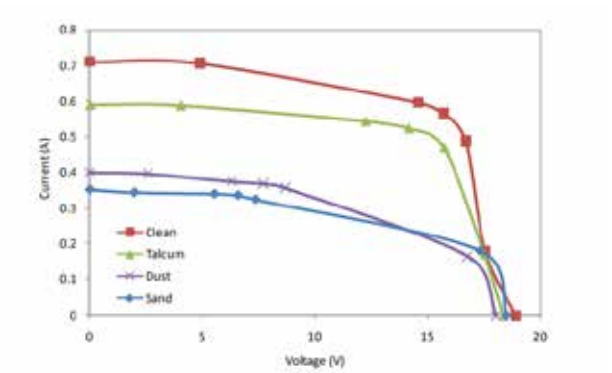

Figure 2: Decrease in power output of solar panels depending on different type dirt accumulation [2]

Current drone based solutions are either prohibitively expensive or lack the precision and durability required for commercial use. This project adressess these challenges by developing a manually controllable cleaning drone capable of operating in urban and industrial environments.

Key requirements include a 15-minute minimum flight time, a 10-meter operation height above the ground, and a lightweight (<15 kg) design with IP22 rated water and dust resistance. The drone must also integrate collision avoidance systems and dual orientation spray nozzles for versatile cleaning of both vertical windows and horizontal solar panels. Adhering to international standards such as ASTM F2910 for small unmanned aircraft systems and ASTM F3005 for battery specifications, the project ensures that all components meet rigorous safety and performance criteria.

Figure 3: Rendered view of the cleaning drone design

Through iterative design, simulation, and prototyping, this system provides a cost-effective and scalable solution to the challenges of maintaining solar panel efficiency and the aesthetics of high rise buildings facades.

[1] H. González Jorge, L. M. González de Santos, N. Fariñas Álvarez, J. Martínez Sánchez, and F. Navarro Medina, "Operational Study of Drone Spraying Application for the Disinfection of Surfaces against the COVID-19 Pandemic," *Drones*, vol. 5, no. 1, p. 18, Mar. 2021, doi: https://doi.org/10.3390/drones5010018.

[2] S. Rehman, M. A. Mohandes, A. E. Hussein, L. M. Alhems, and A. Al-Shaikhi, "Cleaning of Photovoltaic Panels Utilizing the Downward Thrust of a Drone," *Energies*, vol. 15, no. 21, p. 8159, Nov. 2022, doi: https://doi.org/10.3390/en15218159.

Design

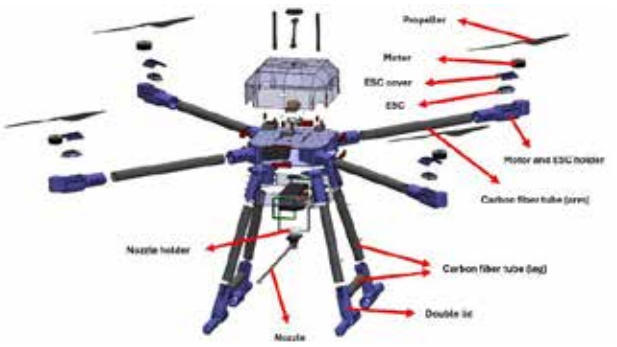

Figure 4 : Wide exploded view

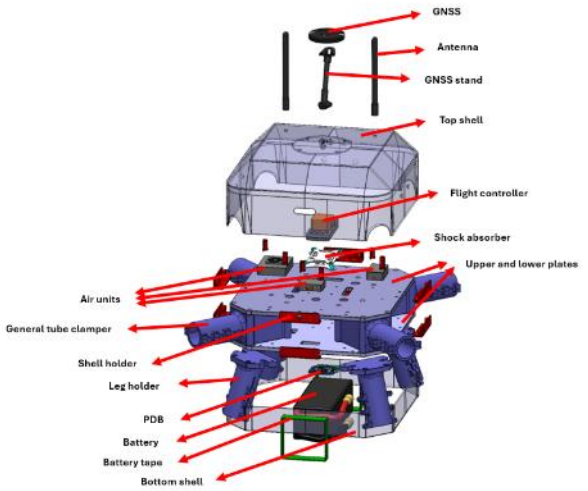

Figure 5 : Zoomed exploded view

The drone adopts an X-frame quadcopter configuration with carbon fiber arms (34 mm inner diameter, 500 mm length) and 3D-printed PLA joints, optimized for weight reduction and structural integrity. A ground-based liquid transmission system comprising a 100L tank, 1HP pump, and 3/4" hose eliminates onboard water weight, extending flight time. The propulsion system features four T-Motor MN501-S KV 240 brushless motors controlled by T-Motor Flame 60A ESCs, paired with P22×6.6 carbon fiber propellers for thrust efficiency.

The Pixhawk Orange Cube+ flight controller processes data from a TFmini Plus LiDAR and GNSS HERE 4 module to enable stable navigation and obstacle avoidance. For cleaning, spray nozzle (300 kPa pressure) is mounted on an adjustable aluminum sheet, allowing between vertical and horizontal orientations. Electrical components are housed in a sealed PLA shell with O-rings, adhering to IP22 standards, while brass insert reinforced joints ensure durability.

Outcomes

This project is the integration of advanced mechanical engineering techniques and standards acquired during the dynamic, control systems, mechatronics and mechanics and materials courses. It is done in several steps through the 2024-2025 academic year given as below:

- Literature research and concept development
- Determining the system requirements and constraints in collaboration with
- Sports International
- Engineering calculations and analysis:
  - 6 DOF system modelling and simulation
  - Electrical and control system integration
  - Static structure and nodal analysis
  - Fluid flow calculations
- CAD drawings and 3D printing of components
- Prototype development:
  - Manufacturing and assembly
  - Design verification and testing
- Safety and compliance checks

G10: Hakan ÖZTÜRK

Bilkent University Mechanical Engineering students are developing a glass-cleaning drone for SPORTS INTERNATIONAL. The project focuses on creating drone that can efficiently clean windows and glass surfaces in high-rise buildings and also solar panels. The students are integrating advanced sensor technologies to enable the drone to navigate around structures, detect dirt, and precisely clean the glass. This innovative solution aims to reduce labor costs, increase safety, and provide an eco-friendly alternative to traditional window cleaning methods, offering great potential for the commercial cleaning industry. It was very valuable for us to be with the students in this project and contribute to their development.

Bilkent Üniversitesi
Makine Mühendisliği Bölümü

METEKSAN SAVUNMA

Design and Production of a Deployable Antenna

WaveRunners (G11)

Academic Advisor : Assoc. Prof. Dr. Onur Özcan
Industrial Advisor : Cankut Erkaya
Teaching Assistant : Ege Özkan

ABSTRACT

The aim of this project is to design and prototype a deployable antenna system for field applications requiring rapid and autonomous deployment. Traditional antenna systems are often are bulky and non-redeployable, making them inefficient in terms of portability and reusability. This project focuses on developing a lightweight and compact antenna that can transform from a storage configuration into a plano-concave operational form via a lead screw-based linear motion system. The structure is actuated by a motor controlled through an Arduino-based control system, which receives input from a wind sensor to allow for automated deployment triggered by environmental conditions. The design ensures that no fasteners need to be removed during deployment, improving usability and maintenance. The antenna structure, which collapses into a thin cylindrical form for transportation, meets strict dimensional and weight constraints while incorporating inexpensive and accessible materials. The final product demonstrates a robust, cost-effective, and efficient deployable antenna concept suitable for both commercial and defense-related field operations.

Problem Definition

Directional receiver antennas receive signals in one direction which enables focused signal transmission, and play a vital role in long-distance point-to-point communication, satellite communication, and defense industry. They are used to concentrate the radiated power in one direction and strengthen signals in an area. Directional antennas are advantageous due to improved reception, less noise, longer range of communication, and strong signals. Automatic deployment and resistance to unforeseen damage are especially critical for military use, where systems must quickly adapt to rapidly changing conditions.

Figure 1: Military Directional Receiver Antenna [1].

The solution focuses on improving a previous directional receiver antenna by redesigning its reflector through mechanical engineering principles to meet more advanced operational needs. The redesigned reflector allows compact stowage and automatic deployment.

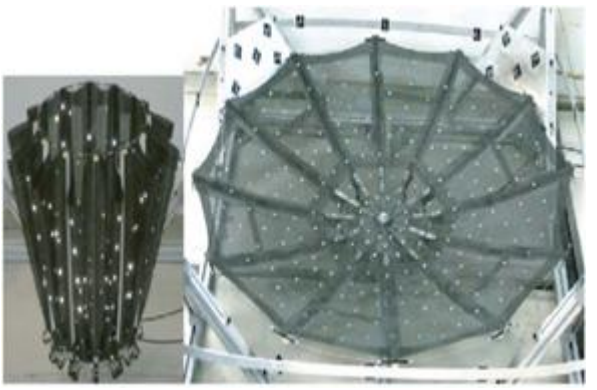

Figure 2: Umbrella-like Deployment Scheme [2].

Previous manually deployable reflector solution had strengths in affordability and portability. However, it lacked automation, required tools for assembly, and occupied significant space when stowed. These limitations reduced mobility and increased deployment time and labor demands in the field.

In terms of operation, the system needs to be sensitive to wind speed, which triggers automatic deployment. The exact dimensions of the solution product are defined by Meteksan Defense.

The solution product will be subjected to ISO 2768 - General Tolerances for Linear and Angular Dimensions, IEC 60529 - Degrees of Protection Provided by Enclosures, IEEE 145 - Standard for Definitions of Terms for Antennas standards.

[1] "Types of Military Antennas", *Antenna Experts*, 2023. [Online]. Available: https://www.antennaexperts.co/blog/types-of-military-antennas. [Accessed: Apr. 10, 2025].

[2] F. L. Jimenez, "Mechanics of thin carbon fiber composites with a silicone matrix," Ph. D. dissertation, Phil., California Institute of Technology, Pasadena, Jan. 2011. [Online]. Available: https://www.researchgate.net/publication/50876712_Mechanics_of_thin_carbon_fiber_composites_with_a_silicone_matrix

Design

Figure 3 : 3D Model of the System

Figure 4 : 3D Model of the Ring

The proposed system is a deployable antenna mechanism consisting of a central pipe, six vertical scissor assemblies, and two ring components. The scissor mechanisms, symmetrically positioned around the central pipe, are constructed using square aluminum profiles and assembled with bolted joints that permit rotational motion. In each scissor assembly, three different profile lengths are utilized to achieve the desired concave geometry.

The top ring is fixed, while the bottom ring is designed to move vertically. Both rings are manufactured from aluminum annular sections and are connected to the scissor mechanisms via U-shaped brackets, allowing for smooth expansion and retraction. The vertical displacement of the bottom ring is actuated by a lead screw mechanism located inside the central pipe.

The system integrates a control unit housed within the central pipe and a wind sensor positioned externally. When the wind speed, as detected by the sensor, exceeds a predetermined threshold, the microcontroller activates the motor to initiate deployment.

Outcomes

This project is a multidisciplinary mechanical design effort developed within the scope of the senior design course. It incorporates knowledge gained from courses such as Dynamics, Control Systems, Mechatronics, and Design of Machine Elements. The project has been carried out over the 2024–2025 academic year through the following phases:

- Literature research
- Determination of system requirements in collaboration with Meteksan Defense
- Engineering analysis including:
  - Static Structural Analysis
  - Kinematic Analysis
  - CFD Analysis
- 3D modeling and detailed CAD drawings
- Safety and risk analysis including FMEA table creation
- Prototype manufacturing using 3D printing, PVC structures, and off-the-shelf components
- Integration of electronic components including Arduino, motor driver, DC motor, and wind sensor

Bilkent Üniversitesi
Makine Mühendisliği Bölümü

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Automatic Cable Winding Drum

Rolling Cables (G12)

Tuna Metin | Mirabel Alsu Bayazıt | Beril Sülü | Turan Yılmaz | Doğukan Baysal

Academic Advisor : Assoc. Prof. Dr. Selim Hanay
Industrial Advisor : Emre Ertürk
Teaching Assistant : Ege Özkan

ABSTRACT

In military and industrial applications, the use of external Ethernet and fiber optic cables is crucial for maintaining uninterrupted communication and data transfer. However, manual handling of these cables can be inefficient, labor-intensive, and prone to damage. This project aims to design and manufacture a compact, durable, and automated cable winding drum system to streamline cable management and reduce the risk of cable wear and operational delays. The system is built to support two different types of cables with independent motors and controlled winding speeds. It is powered by a 24V DC source and designed to comply with military durability standards. A Raspberry Pi serves as the central controller, allowing for precise speed control and future integration of advanced features. By automating a typically manual process, the project offers a practical and efficient solution for field deployment environments where reliability and speed are critical.

Problem Definition

The deployment and retrieval of long cables in dynamic and harsh environments, such as military field operations or mobile communication systems, require quick, safe, and organized handling. Traditional manual systems often lead to tangled cables, physical strain on personnel, and increased maintenance due to cable damage. In applications where both Ethernet and fiber optic cables are used simultaneously, managing each type with care becomes even more complex. Moreover, current automatic cable management systems are either too bulky for vehicle integration or fail to meet the ruggedness required for outdoor and mobile applications. This project addresses the need for a compact and reliable cable winding solution that can handle two different cable types independently while offering robust control, portability, and resistance to environmental conditions. By designing a speed-controlled, dual-drum cable winding mechanism compatible with military vehicles, the project provides an innovative alternative to inefficient manual systems.

Our project proposes the development of an advanced dual-mode cable winding system tailored for military land vehicles. The system operates through a drum mechanism powered by an electromechanical system. As the drum rotates, it enables the cable to be wound and unwound efficiently. To ensure even distribution of the cable along the drum, a guiding system is integrated into the design. To maintain optimal cable tension and prevent issues such as over-tensioning, slack, or tangling, the system incorporates sensors like load cells and rotary encoders. These sensors dynamically adjust motor performance as needed. Additionally, a manual mode is included, allowing personnel to operate the system using a crank handle in case of power failure.

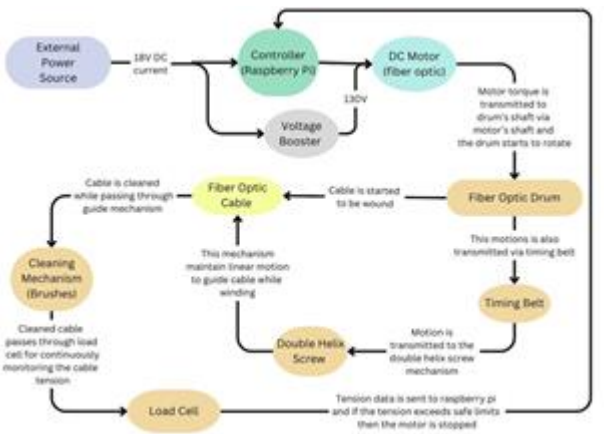

Figure 1: Flowchart for the working principle

The solution product will be subjected to MIL-STD-810 G standard, which is used for Environmental Engineering Considerations and Laboratory, and ISO 2768 M, meaning a 20 mm dimension without a specified tolerance will have an allowable deviation of ±0.2 mm, is used to ensure proper fits and prevent misalignments. Also, MIL-STD-461 G is used for motor selection adhered to electromagnetic interference immunity guidelines to minimize noise emissions in military environments.

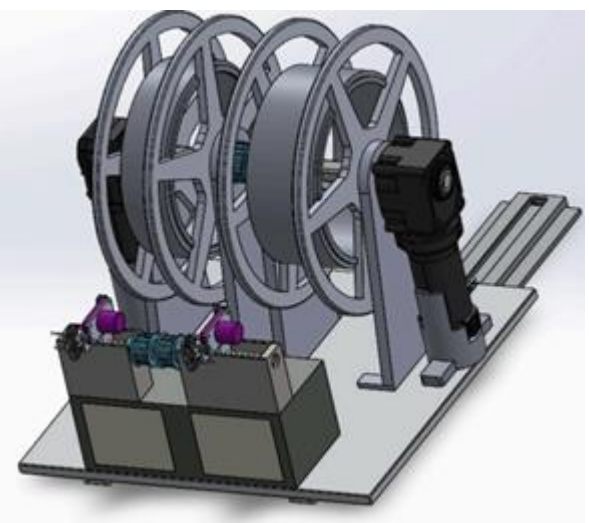

Figure 2 : 3D model of the final design

Design

The cable winding drum system consists of two independently powered drums, each responsible for winding either an Ethernet or a fiber optic cable. The mechanical structure is constructed using aluminum sigma profiles for modularity and ease of assembly. Each drum is driven by a brushed DC motor selected based on torque, compactness, and compatibility with MIL-STD-810. A custom motor mount and frame ensure stable operation even under vibration or uneven motion. A Raspberry Pi is used as the main controller, programmed to manage motor speed and direction. Motor drivers are chosen for their ability to handle up to 10A of current and integrate easily with the Raspberry Pi's GPIO interface. Cable routing components are placed to prevent overlap or tangling, and sensors can be optionally integrated for detecting the start and end of cable travel. The system's design emphasizes modularity, allowing the entire unit to be mounted onto a variety of vehicle surfaces and easily adapted for future needs such as feedback control or automated deployment triggered by vehicle commands.

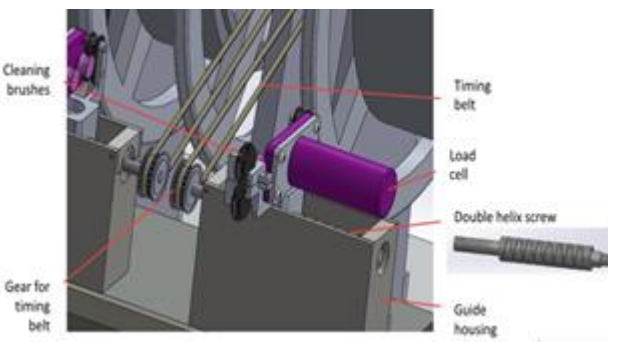

Figure 3 : Exploded view and definition of components for guiding mechanism

One of the most critical aspects of the design is the guide mechanism, which ensures uniform layering of cables during winding. To maintain compactness and mechanical simplicity, the guide mechanism is driven mechanically via gears and a timing belt connected to the drum's main shaft. At the core of this system is a double helix screw, which enables smooth left-right translation of the cable guide across the drum width. The screw ensures consistent layering and reduces the risk of tangling, overlapping, or uneven tension.

Outcomes

This system is a mechanical design project that combines the mechanical engineering knowledge acquired at dynamics, control systems and mechatronics courses. It is done in several steps through the 2024-2025 academic year given as below:

- Literature research
- Determination of sub-systems according to requirements provided by ROKETSAN
- Engineering analysis including:
  - Torque and speed calculations for motor selection
  - Power transmission design using gears and timing belts
  - Mechanical design of the double helix screw-based guide mechanism
  - Material selection and strength analysis for frame and rotating components
- CAD drawings
- Embedded system design
- Safety Analysis
- Planning of manufacturing processes, assembly, design verification and testing of the system

G12: Emre ERTÜRK

Bilkent Üniversitesi
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Design and Production of a Payload Lowering System for Underwater Applications

BilME TopSecret (G13)

Academic Advisor : Asst. Prof. Dr. Orçun Koray Çelebi
Industrial Advisor : Ender Kurukahveci
Teaching Assistant : Yiğit Yaman

ABSTRACT

This project aims to design a compact and robust payload lowering system for controlled underwater deployment and retrieval. The system must submerge a payload to specific depths in a saltwater environment while maintaining its stability within designated pitch and roll limits and retrieve it with high precision structural integrity and balance. To address this challenge, a telescopic lifting system and a screw-driven horizontal actuation mechanism were developed. The prototype emphasizes structural stability, corrosion resistance, and mechanical precision. This project supports underwater operations such as defense, maintenance, and inspection, potentially contributing to technological advancements in maritime systems.

Problem Definition

Underwater operations such as inspection, maintenance, deployment, or retrieval of equipment pose significant challenges due to the harsh marine environment and the complexity of precise control in submerged conditions. These operations are particularly critical in sectors like defense, energy, telecommunications, and marine research, where human involvement is often limited due to safety concerns, operational risks, and cost factors.

The objective of this project is to design and develop a system that can be mounted onto portable systems to perform the controlled lowering and retrieval of a payload into saltwater. The system must ensure that the payload remains stable at a desired depth and orientation despite external disturbances such as water currents or uneven loading. The loading process must be reliable, repeatable, and operator-controlled through an integrated electromechanical interface.

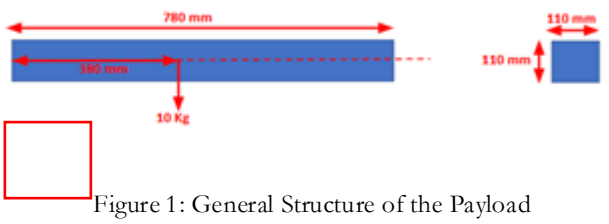


Figure 1: General Structure of the Payload

In terms of engineering constraints, the system must operate within limited space—maximum dimensions are 400 mm in height and 255 mm in width. It must also maintain a weight below 42 kg (excluding the payload). The payload must be lowered and held at a depth of 550–750 mm from the dock, and angular stability should be ensured within ±5° roll and ±3° pitch under submerged conditions.

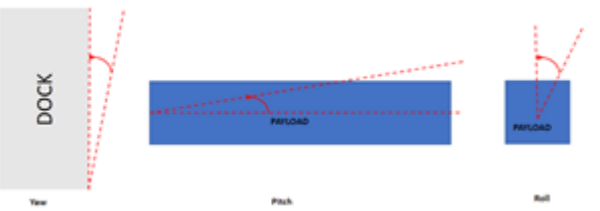


Figure 2: Pitch and Raw Angles

Figure 3: The payload lowering into the water from a vessel [1]

Additionally, the system is expected to handle external forces up to 80 Newtons of axial force, which can be applied from the payload, and should hold the payload stationary at the desired position. Stability and static control over yaw angle must be between 3° and 10° and must also be preserved during the processes like lowering, holding and lifting

The system should be corrosion-resistant, mechanically robust, and compatible with industrial manufacturing processes. It should allow safe deployment and retrieval cycles through motorized, sensor-based control and be easily integrated into portable systems for operating in maritime conditions.

[1] Miller, R. (2016, April 20). *Microsoft may deploy more undersea data centers*. Data Center Frontier. https://www.datacenterfrontier.com/design/article/11431244/microsoft-may-deploy-more-undersea-data-centers

Design

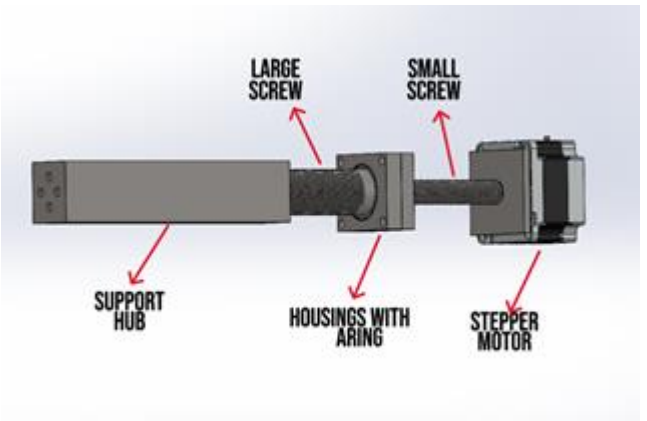


Figure 4: CAD Model of the Screw System

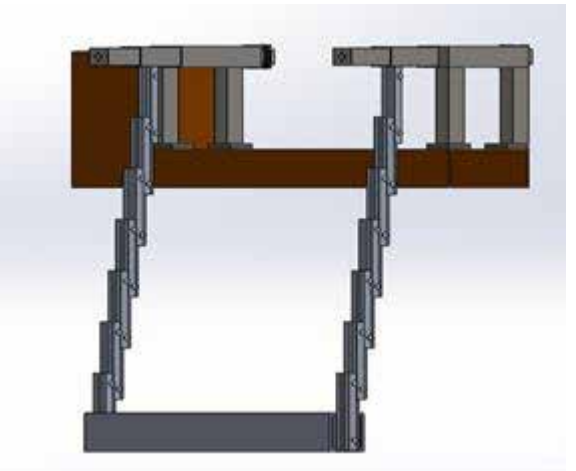


Figure 5: CAD Model of the System

The final design includes a rectangular telescopic platform and a screw-based horizontal movement mechanism. The telescopic system is composed of interlocking aluminum profiles that extend smoothly with the help of precision-manufactured pulleys and steel ropes driven by DC motors. For accurate horizontal control, a screw mechanism with stepper motors was implemented. The screw system converts rotational motion into precise linear displacement via a screw mechanism, ensuring low friction and high stability.

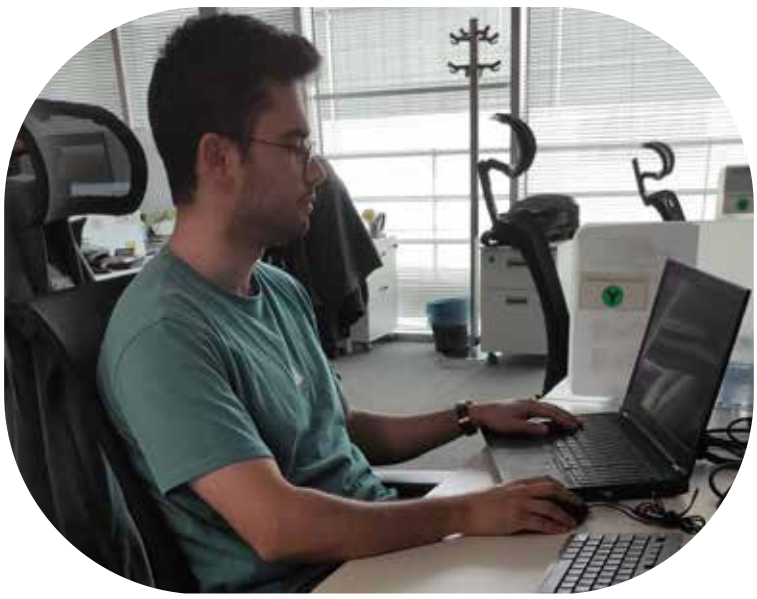
ANSYS simulations were used to validate the design under expected loading conditions. Material selection was guided by weight limits, corrosion resistance, and structural integrity. The main telescopic components were manufactured from 3000 series aluminum, which offers good corrosion resistance against seawater contact and makes it suitable for marine applications. Components exposed to high loads, which are mainly horizontal screw mechanisms, were produced from AISI 304 stainless steel to provide excellent resistance against pitting and long-term environmental wear.

Outcomes

This project is a mechanical design project that integrates mechanical engineering knowledge from mechanics of materials, dynamics, control systems, and design courses. It was carried out during the 2024–2025 academic year in the following steps:

- Literature research and examination of current underwater deployment systems
- Defining system requirements and constraints with academic and industrial mentors
- Creating a conceptual design and selecting the best alternative using a design matrix
- Engineering analysis, including:
  - Static stress analysis using ANSYS
  - Stability and deflection calculations under load
  - Angular constraint evaluation (pitch, roll, yaw)
- CAD drawings
- Prototype manufacturing
- Safety considerations and emergency stop system implementation
- Budget planning and risk assessment for manufacturing and testing phases

G13: Ender KURUKAHVECİ



Bilkent Üniversitesi
Makine Mühendisliği Bölümü

Door Opening and Closing Mechanism for Advanced Drying System

Two Guys (G14)

Selim Tuğrul Çandar **Muhammed Baran Özbahçe**

Academic Advisor : Prof. Barbaros Çetin
Industrial Advisor : Batur Zafer
Teaching Assistant : Altar Sertpoyraz

ABSTRACT

This project introduces an automatic door opening and closing mechanism designed for Beko dishwashers, aiming to enhance drying performance through smart, energy-efficient operation. Unlike traditional systems, the developed design enables the dishwasher door to open automatically after the washing cycle and close again once safe environmental conditions are met. The mechanism uses a motor-driven cam system to control the motion of a snap-fit locking structure. Manual control remains fully functional. It is compatible with current dishwasher models and requires minimal structural modifications. Sensors monitor humidity and temperature, triggering the automatic closing when appropriate. Early prototypes were created with 3D printing, while final parts will be produced with industrial-grade materials by Beko. The system has been tested both virtually and physically, offering a practical and user-friendly solution for modern dishwashers.

Problem Definition

Dishwashers have become an essential appliance in modern households, frequently used for daily cleaning tasks. Users typically open the dishwasher by pulling an external handle located on the front door. However, in built-in models, this handle can disrupt the sleek and uniform appearance of kitchen cabinetry. As kitchen designs evolve toward minimalism and visual integration, removing visible handles has become a desirable trend, pushing manufacturers to seek more elegant, functional, and hidden door-opening solutions.

Figure1: Sample Beko Diswasher [1].

This project offers a smart solution for Beko dishwashers by developing an automatic door mechanism that opens after the washing cycle and closes once drying is complete. The system uses a compact cam- driven motion unit that fits near the existing lock without altering the door's structure. Its integration preserves manual usability and enables seamless operation in fully built-in models, enhancing efficiency.

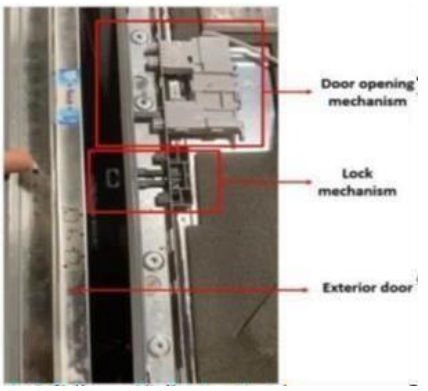


Figure 2: Beko's Auto Door Opening Mechanism Placement [2].

The developed mechanism automatically opens the dishwasher door at the end of a cycle to release steam and closes it once environmental conditions are safe. A humidity or temperature sensor detects these changes and sends signals to activate the system. This controlled motion improves drying performance while maintaining safety. The predefined door opening angle ensures efficient steam escape without posing risks. The motion is smooth and quiet, creating a better user experience. Manual override is always available, allowing the user to open or close the door when desired. Designed for full integration, the mechanism operates behind a decorative kitchen panel without affecting the overall appearance. It fits within the available space and aligns with existing components. Early prototypes were successfully tested using 3D printing.

[1-2] B. Zafer, "Door Opening and Closing Mechanism for Advanced Drying System," Project Proposal, Bilkent University, Dept. of Mechanical Engineering, in collaboration with Beko Dishwasher Plant, Aug. 23, 2024.

Design

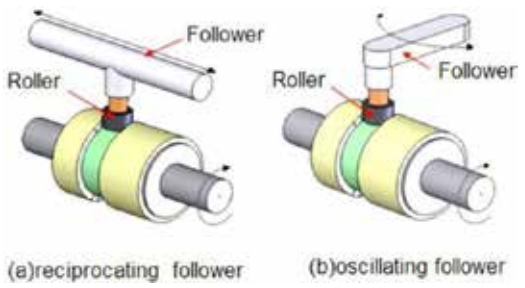


Figure 3 : Cylindrical Cam Principles

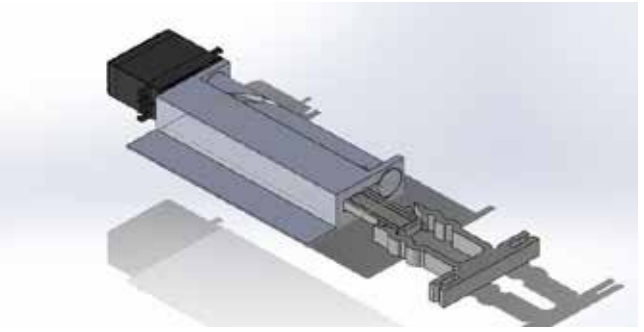


Figure 4 : Design of the Mechanism

The proposed mechanism operates through a motor-driven cam system that transforms rotational motion into linear displacement. The system primarily consists of two subsystems: a rotary actuator (servo motor) and a mechanical pusher integrated into a compact housing. The rotary cam pushes a rectangular arm forward, enabling controlled movement of the locking element. The system is designed to minimize part count, enhancing reliability and reducing failure risk. Positioned behind the decorative panel, the mechanism functions automatically based on programmed signals. It ensures seamless door operation without requiring significant space. All components are optimized for easy assembly and integration into existing dishwasher models.

The mechanism operates based on control signals received from environmental sensors such as humidity or temperature detectors. When the sensors detect that drying conditions are met, a signal is sent to the microcontroller. This signal triggers the servo motor, causing the cylindrical cam to rotate and push the rectangular arm forward, unlocking and opening the door. Afterward, once safe conditions are detected, another signal initiates reverse motion to close the door. If no trigger is received, the system remains inactive. This logic ensures the door only moves under controlled circumstances, improving safety and performance without disrupting manual usability.

Outcomes

This project represents a mechanical system development that applies core engineering knowledge from dynamics, mechanisms, and mechatronics courses. Throughout the 2024–2025 academic year, the team followed a structured process including:

- Literature and market research
- Sub-system design based on Beko's requirements
- Engineering analyses: linkage design, motion simulation, and fatigue testing
- Detailed CAD modeling of the cam, arms, and housing
- Sensor integration for automatic closing

This Project was funded by TUBİTAK 2209-B

G14: Batur ZAFER

The team is smaller compared to others. However, they compensated by working at least twice as much. They researched the topic well, made several immaculate analyzes to choose their design. After the decision, they made even more analyzes to confirm the choice. During this period, they informed me well about the processes while also taking my suggestions and warnings into account. Overall, I am happy with the engineering they applied and the communication they provided. I hope to see the design as soon as possible and I wish it will also reflect the engineering they put into it.

Editors:

Prof. Barbaros Çetin

Doç. Dr. Müjdat Tohumcu

Ela Baycan

Ela Bahşi

Ege Erdoğan

Elfin Gül

Altay Yıldız

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ISBN: 978-605-9788-65-6