F22-21-BOE1 - Big Boeing Brand

Client: Boeing through SIU

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By: Samuel Kash (EE), Ben Trewin (ECE), Nicolas Forcade-Perkins (CE), Dylan Houghland (CE), Mason McFarland (CE)

Team - Big Boeing Brand

- Nicolas Forcade-Perkins (CE and Math)
- Mason McFarland (CE)
- Dylan Houghland (CE)
- Benjamin Trewin (ECE)
- Samuel Kash (EE)

Diversity in experiences

Working As A Team

- Made sure everyone was working on a subsection that they could succeed at and were interested in
  - Sam doing manufacturing
  - Ben working on controller
  - Mason doing circuit design for metal detector
  - Dylan working on 3D printing claw
  - Nic building machine learning model for object detection
- Great communication between everyone
  - Weekly meetings and group chat

Project Description

- Search and Rescue (SAR) robot for Boeing
- Needs to be able to maneuver over a 6” wooden post
- Has to detect metal and pick up different objects
- Must be controlled with low latency and be able to turn around in <5 seconds
- Must be semi-autonomous by maneuvering through a maze

Project Motivation

- Sponsored by Boeing so we want to represent the SIU ECE department well
- Helps us learn how to work on a large-scale project

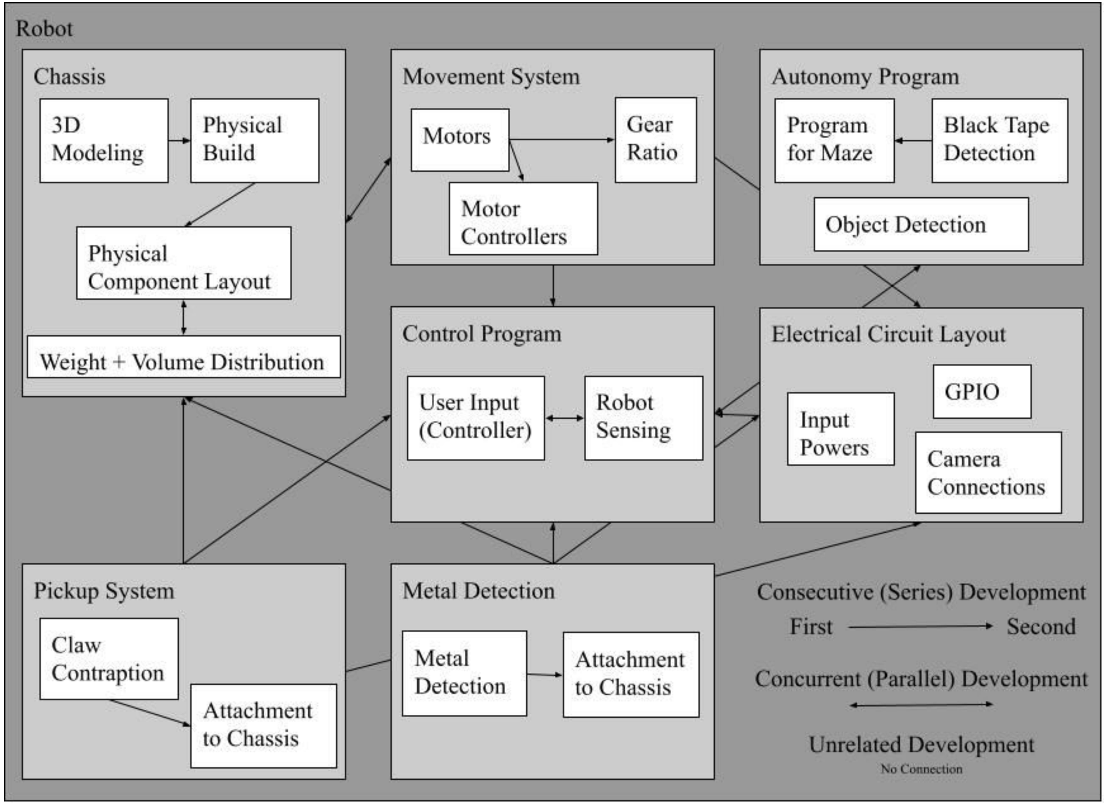
Constraints

- **Economic** - Must design our robot with a budget of under $1000.
- **Environmental** - Plan to use rechargeable batteries which will reduce waste and donate our robot at the end to the ECE department so that the parts can be reused next year.
- **Social** - Our robot doesn't have any social constraints.
- **Political** - Our robot doesn't have any political constraints.
- **Ethical** - Because our robot will be semi-autonomous, we will ensure that there is nothing unethical in any programs we produce. Further, we will document open-source code utilized and not play it off as our own developments.
- **Health and Safety** - Goal of the robot is to be able to search and rescue small objects. Could be used in situations where it isn't safe for a human to enter.
- **Manufacturability** - Our robot needs to be able to be built in under 1 year. Further, it should ideally be built to have a final volume $<2ft^3$.
- **Sustainability** - Plan to use rechargeable batteries which will reduce waste and donate our robot at the end to the ECE department so that the parts can be reused next year.

Constraints - Boeing (Product) Specific

- Low latency controls - must be responsive to controller in <.5s
    - Controller must run as Android app over Bluetooth connection
- Claw to pick up 16 oz can
- Partial autonomy
    - Navigate through maze
    - Detect objects in an image
- Detect metal washers in a pile of sand
- Navigates over different size logs

Flowchart of Subsystems



Subsystem Descriptions

- Chassis
  - Manufacturing body of robot from square tubing. Provides frame to hold motors and pulleys.
- Movement System (Drivetrain)
  - Movement will be created by 4 motors turning two treads with gear reduction ratios to increase torque. PWM with motor controllers will be used to control speed/direction of movements.
- Pickup System (Claw)
  - Consist of two servo motors. One servo motor controls the arm of the claw, moving it vertically. The other servo motor is attached to a gear that pulls the dynamic “hand” of the claw to tighten grip.
- Metal Detection
  - The metal detector features a small circuit constructed from resistors, capacitors, transistors, a potentiometer, and a buzzer. This design should allow for approximately 60mm of detection depth through coils with a diameter of 86mm.

Subsystem Descriptions Cont.

- Electrical Circuit Layout
  - Determined physical circuit connections to make so that all movement and peripheral devices were supplied proper voltage and current
- Control program
  - Created a user interface that connects to a Rasp Pi over Bluetooth and allows the robot to be controlled
- Autonomy
  - Used IR sensors and an algorithm to detect the edges of the maze and navigate accordingly
  - Built a Convolutional Neural Network in PyTorch that allowed the Pi to recognize logs, cans, cubes, and spheres

HoQ

- A = most important, F = least
- Less than $1000 (A)
- Less than 0.5 sec latency (C)
- Less than 5 sec 180° turn (C)
- Scale 6” log and post (B)
- Carry items (C)
- Less than 2 cubic feet volume (B)
- Metal detection capability (D)
- Maze travel autonomy (A)
- ROS integration (F)
- Controlled through app (C)

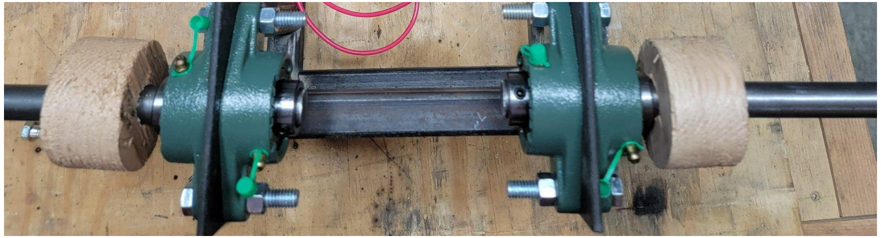
1 to 5 Customer Priority		Customer Requirements	Technical requirements	1 Horsepower	2 Tracks/Wheels	3 Weight	4 Bluetooth strength	5 Metal detection accuracy	6 Pickup tool	7 Battery life	8 Raspberry pi	9 Chasis	10 TA 10	Customer Assessment / Competitive Evaluation (1-5 scale with 5=best, 1=worst at meeting customer requirements)	Boeing Team 2	Previous Boeing Team F2021-S2022	Previous Boeing Team 2021-22 Team 2	Robot found on Blog (https://www.sciencebuddies.org/science-f
		Target or direction			↓	•			•	↓		↓						
5	1	Autonomy			3					1	6				5	1	3	1
5	2	Less than $1,000		9	3		3	3	3	6	9	3			3	5	5	5
3	3	Less than 0.5 sec latency					9		6		6				5	1	2	4
3	4	180 Deg. Turn < 5 Sec		6	6	3						1			1	2	1	5
4	5	Scale 6x6 log		9	9	9	3		1			6			3	2	1	1
3	6	Carry items		3	3	3	3		9						3	2	3	1
4	7	> 2 cu. ft. Volume		3	6	3			6			9			5	4	4	5
2	8	Data Monitoring					6			6	9				1	2	1	1
2	9	Metal Detection						9			6				3	1	3	1
		Importance Rating Σ(priority×relationship)		135	117	66	75	33	88	47	123	78	0					
		Technical Assessment		+	-	+	+	+	-	-	+	-	+					

Description of 3 Sprints

- Smart goals helped keep us on task with an end of sprint goal that all members needed to contribute to
- Sprint 1
    - Fully completed chassis
    - Built claw
    - Got the robot moving
    - Started controller app
- Sprint 2
    - Mounted claw
    - Mounted metal detector
    - Built object detector
    - Finished controller app
- Sprint 3
    - Autonomous navigation
    - Cleaned up wiring
    - Final testing

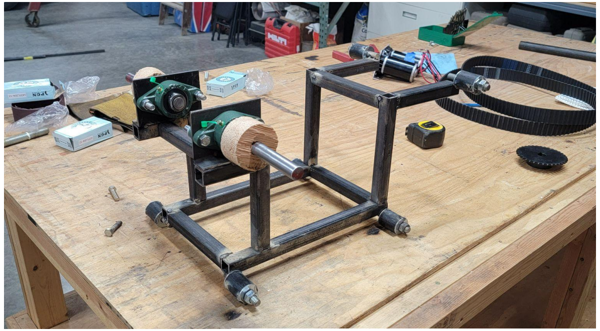
Design Decision - Tracks

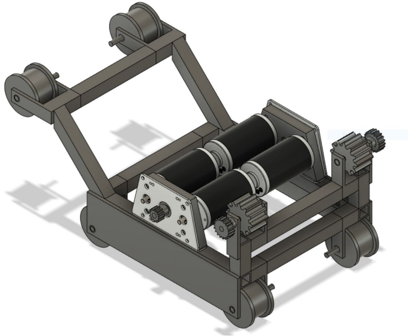
- Tradeoff: used tracks instead of wheels because we felt it gave robot best opportunity to maneuver over obstacles
- The best idea we came up with was using double timing belt. This is a ribbed belt that has ribs on both sides. It is often used in the industrial settings. The ribs on the inside allow it to be driven by a gear like pulley and the ribs on the outside provide traction.
- By using bearings on the drive spindle it will keep our motors from needing to overcome excess friction.
- We planned to use metal pulleys but after months on backorder, that ordered was then cancelled by the vendor so we 3D printed them instead.

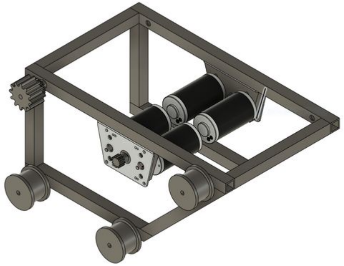


Design Decision - Frame

- With motor and tracks chosen we constructed the frame. We had 1” square tubing at our disposal as well as a welder.
- Tradeoff: Chose metal tubing because it was sturdier even though plastic would have been lighter.
- The frame needed to allow for sufficient height the bottom side of the track to clear the top of the 6” log. The idea is if it starts out above the object it should cover come the obstacle easier.

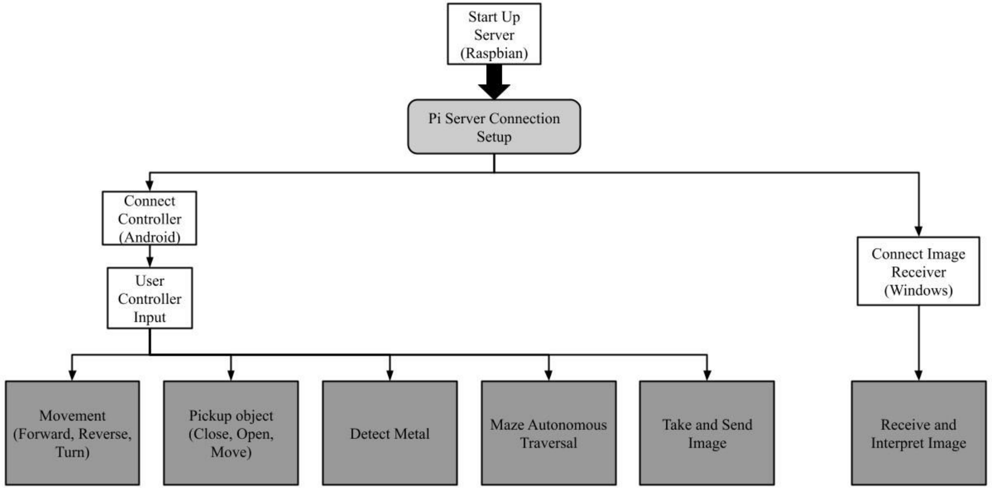






Design Decision - Controller

- Created basic Bluetooth based controller app for Android devices that allows connection with Raspberry Pi
- Tradeoff: used Bluetooth over wifi because the robot could be controlled anywhere regardless of wifi availability
- Tradeoff: used GUI library named Kivy for GUI creation within python rather than coding the the GUI in another language and needing to interface between languages for Bluetooth communication (beyond scope of the project)



Standards

- IEEE 802.15.1-2002 - Bluetooth Standard
- IEEE 1625-2008 - Standard for rechargeable batteries
- IEEE 26513 - Standard for programming and testing code
- IEEE 1118-1990 - Standard for serial communication for micro-controllers

Courses

- ECE 321, Intro to Software Development
    - Learned how to program using C.
    - Will apply this course and the development practices learned in it while developing the code to run the robot.
- ECE 296, Intro to Software Tools and Robotics
    - Learned Python and how to build robots
    - Learned how to program Arduino's and Raspberry Pi's
- ECE 345, Electronics
    - Helped us plan the circuit design for controlling the motors and creating the metal detector.
- ECE 385, Electric Machines
    - Helped us understand some of the basic theory behind motor function and statistics

Tools Used

- Autodesk Fusion 360 - 3D model the design of the chassis and 3D printed parts
- PSpice - Validate the circuit we are planning on using to complete the metal detector
- OS Image - OS to use for Raspberry Pi utilized is Raspberry Pi OS Lite 5.15 (32-bit)
- VM Virtualbox - Used to create virtual linux machine for compiling APKs for use on android devices
- Visual Studio Code - Easy to use code editor
- Physical tools: Band saw, Grinder, Welder, Squares, Clamps, wrenches, hammer

AUTODESK® FUSION 360™

Visual Studio Code

Ubuntu

Raspberry Pi OS

Judgement

- Global
  - Search and rescue robot so able to navigate and retrieve objects from areas that are not safe for humans. This will allow human lives to be saved and have a positive global impact.
- Economic
  - Must design our robot with a budget of under $1000 so had to find cheaper parts
  - Use products from all over the world when ordering parts in order to help contribute to the health of the global economy. This helped us to have cheaper parts, even if the shipping time took a little longer.

Judgement Cont.

- Environmental
  - Used rechargeable battery
  - Used as many recycled parts as possible in order to reduce our carbon footprint.
  - Decided to donate a large portion of the parts on the robot to next year's program in order to reduce waste as much as possible
- Societal
  - Limited in space, but by increasing the size of the claw we could increase the size of objects it is able to pick up.
  - Being able to pick up larger objects allow usage in more situations and hopefully save more lives

Learn - Bluetooth Socket Programming

- With minimal socket experience
  - Utilized PyBluez and PyGenius to establish connections between Android phones, Windows computers, and Raspberry Pis
  - Learned through the use of GitHub, read the docs, stack overflow, and youtube among other sites how to transfer information via Bluetooth
  - Was able to ask questions over discord servers for more information
  - Also benefited with some prior background knowledge from Systems Programing ECE430
  - All socket connections can be created without confusing user in neat GUI Android environment

Success Metrics

A-Level: Meets all requirements fully and receives full points.

B-Level: The robot is able to excel in most categories, but receives deductions in more than one category.

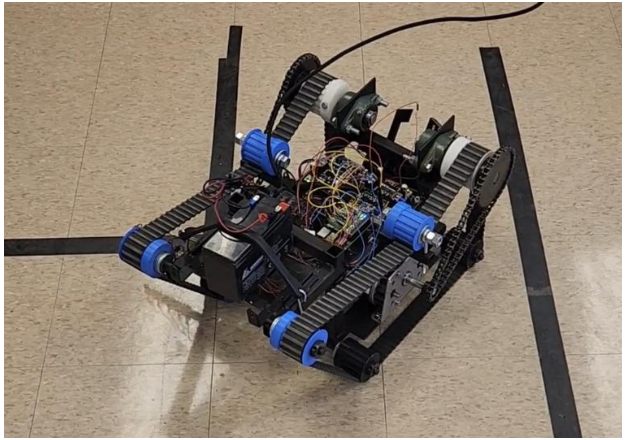
C-Level: The robot meets the lowest requirements on the score sheet and receives the minimum points in all categories.

D-Level: The robot is only able to move and cannot meet any other requirements.

F-Level: The robot doesn't move.

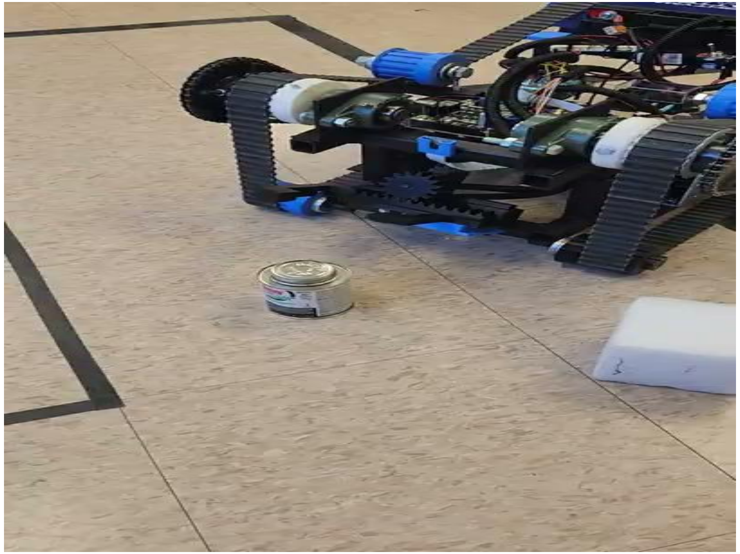
Final Results - Robot and Movement

Meets product constraints but can't get over 6' post and volume is in higher criteria



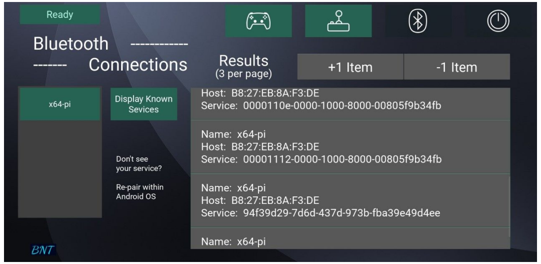
Final Results - Operable Claw and Metal Detection

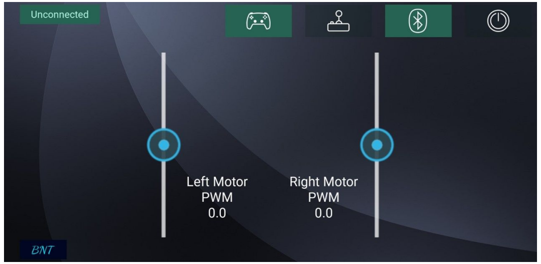
Meets maximum product constraints with some limitations on metal detection

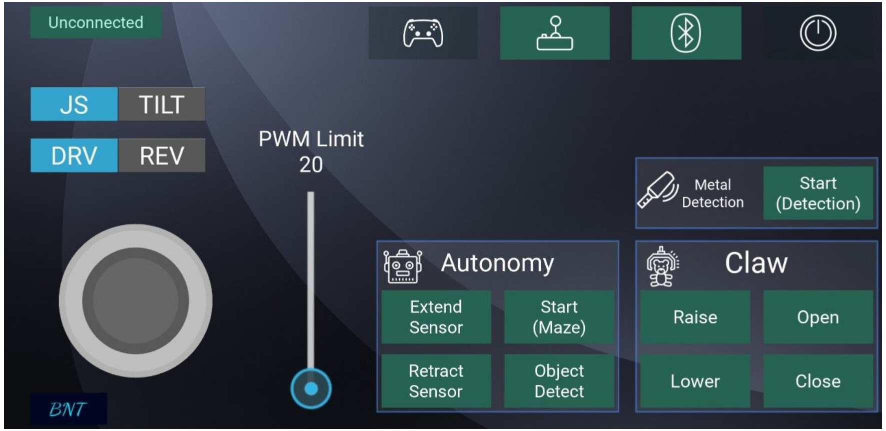


Final Results - Android Based Controller

Meets maximum product constraints

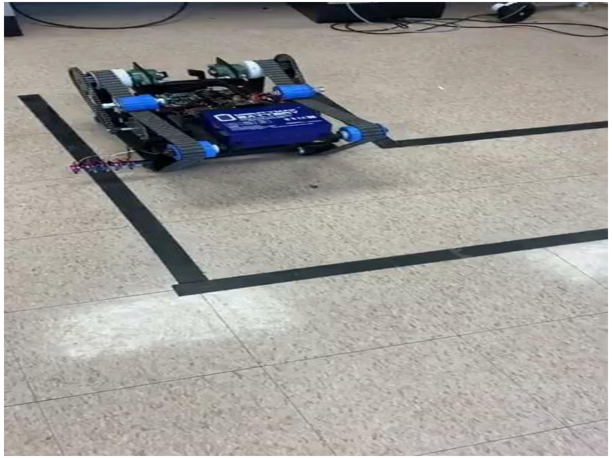


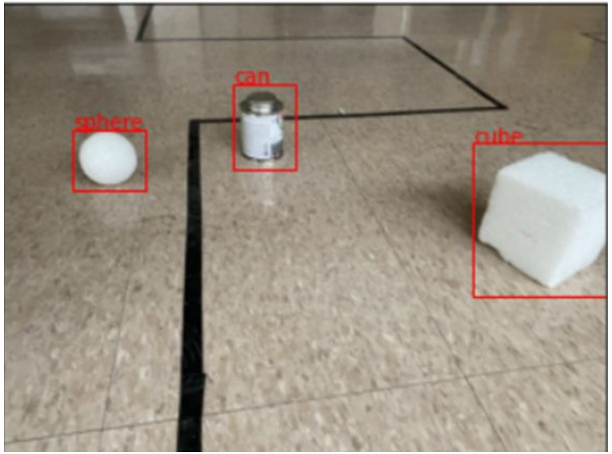


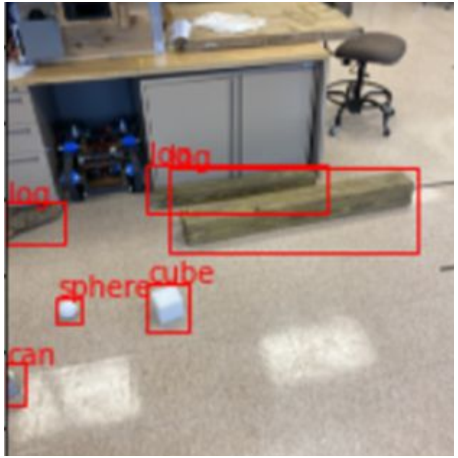


Final Results - Autonomy and Object Detection

Meets maximum product constraints







Conclusion

- Spent <80% of budget (~$800 to build another + ~40 hours manufacturing time)
- Scored highly on Boeing rubric -> B+ on our success metrics
- Lessons learned - General
    - Importance of being decisive and planning ahead
    - Importance of communication when working in a team
- Lessons learned - Specific
    - How to work with motors and power them successfully
    - How to interface devices via bluetooth and GUI creation
    - How to create basic autonomous functions
- Recommendations to future teams
    - Don’t be afraid to pull the trigger and purchase things

Conclusion Cont.

- Each member’s contributions
  - Nic - Autonomy, object detection
  - Dylan - Autonomy, claw
  - Samuel - Chassis
  - Ben - Controller and chassis
  - Mason - Chassis design and metal detector
- Thank you to Evan, our FTA, and Prof. Cubley for all the help throughout the project

References

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