Boston Dynamics

Spot Arm® Safety and Operations Manual

Instructions for Use

Version 2.0
March 2025

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1. Introduction

1.1. About This Document

This document contains critical safety information for Spot Arm.

Responsible use of Spot Arm is crucial to prevent dangerous conditions for those in close proximity to Spot. Read, understand, and comply with this document before initial use of Spot Arm to decrease the risk of injuries or damage to yourself, Spot, or other property.

Spot Arm can only be used with the Spot robot, as an attachment.

REQUIRED READING

Before setting up or operating Spot Arm, review “Spot Instructions for Use” in the Boston Dynamics Support Center (see Appendix A: Supplemental Information).

Spot Arm is intended for integration into a final complete application that includes elements and objects of manipulation. The final application requires a dedicated risk assessment. See General Principles and complete a risk assessment and evaluation of the intended application of Spot Arm before powering it up and commissioning it into a solution. The commissioning party should compile additional Information for Use specific to the final application, including limitations and intended use.

Keep a copy of this document in a readily accessible location. Complete user and developer documentation on the Spot robot platform, including a digital version of this document, is available online in the Boston Dynamics Support Center (see Appendix A: Supplemental Information).

This document is valid for the following designation of Spot + Spot Arm:

Hardware model (P/N):	04-00143531-101 04-00143531-501 04-00143531-701 04-00143531-711
Controller model (P/N):	04-00483754-001
Software	v4.1 and above

1.2. Manufacturer Information

Spot and Spot Arm are manufactured by:

Boston Dynamics, Inc.
200 Smith St.
Waltham, MA 02451
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1.3. Key Terminology

Term	Definition
Spot	A legged robot capable of mobility on a variety of terrains. Spot uses multiple sensors and three motors in each leg to navigate in indoor and outdoor environments, maintain balance and attain postures. Spot is capable of carrying and powering attachments.
Spot Arm	A manipulator with a grasping gripper mounted exclusively on Spot. Spot Arm can be used with and is controlled solely by Spot.
Operator	Any person trained and authorized to manually operate, repair, handle, or supervise the automatic operation of Spot. This definition corresponds to the terms “Qualified person” and “Authorized person” as defined in ISO/TR 22053:2021, Clause 3.4.
Bystander	Any person who can be reasonably expected to be near Spot, but is not an operator. This definition corresponds to the term “Affected person” as defined in ANSI B11.0-2020, Clause 3.4.
Task	An activity performed by a person, including manual operation of Spot.
Operation	An activity performed by Spot, whether as a result of manual or automatic operation.
Mission	A set of instructions and map data that allows Spot to navigate automatically along a known route while performing data capture actions and other operations. The features that allow Spot to record and replay missions are collectively called “Autowalk”.
Action	A predefined operation that can be performed during a mission. The Spot software includes several preset Actions, such as capturing images from robot cameras and docking with a Spot Dock. Custom Actions can be created using Spot’s software development tools.
Attachment	Any device or piece of hardware that is affixed to Spot to enhance or expand Spot’s functionality. Attachments for Spot are commonly called “payloads”.

Term	Definition	
Fiducials		Specially designed images similar to QR codes that Spot uses to match its internal map to the world around it. Fiducials are required at the beginning of every mission. Spot recognizes AprilTag fiducials that meet the following requirements: • AprilTags in the Tag36h11 set. • The default Image size: 146 mm square. • Printed on white non-glossy U.S. letter-size sheets (preferably rigid).

1.4. Legend of Hazard Labels

DANGER

Indicates a hazardous situation which, if not avoided, will result in death or serious injury.

WARNING

Indicates a hazardous situation which, if not avoided, could result in death or serious injury.

CAUTION

Indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.

NOTICE

Indicates information considered important, but not hazard related.

REQUIRED READING

Indicates a mandatory reading of Instructions for Use or other safety-related documentation.

1.5. About Spot Arm

1.5.1. Description of the Machinery

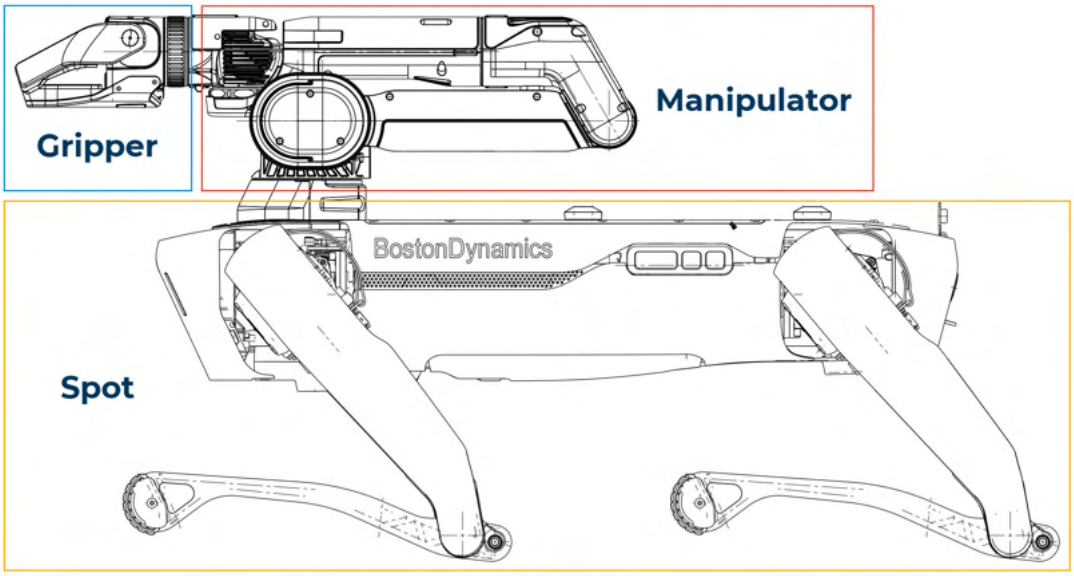
Spot Arm provides general purpose manipulation capability to the base Spot robot. Types of manipulated parts and/or interactions with the environment or equipment are defined when a specific application is determined.

The manipulator provides 6 degrees of freedom. The end-effector ("gripper") has a built-in single degree of freedom.

The combination of Spot and Spot Arm performs locomotion, navigation, and manipulation in a variety of indoor and outdoor environments, using a complex set of control algorithms to manipulate objects while balancing and moving around.

The Spot unit (quadruped part) uses embedded sensors to detect the surrounding environment, while Spot Arm (manipulator part) has no detection sensors.

Spot Arm is compatible with the installation of other attachments on Spot.



Major components of Spot and Spot Arm.

1.5.2. Specifications

Spot with Spot Arm (robot with manipulator and gripper)

Specification	Value
Total weight (with battery)	40.5 kg
Maximum height (Spot at maximum standing height with Spot Arm at maximum vertical extension)	1820 mm

Spot Arm (manipulator and gripper)

Specification	Value
Combined weight	8 kg
Combined length	984 mm
Lift capacity (at 22°C)	Up to 11 kg
Continuous lift capacity at 500 mm extension (at 22°C)	5 kg
Operating temperature	-20°C to 45°C
Ingress protection	IP54

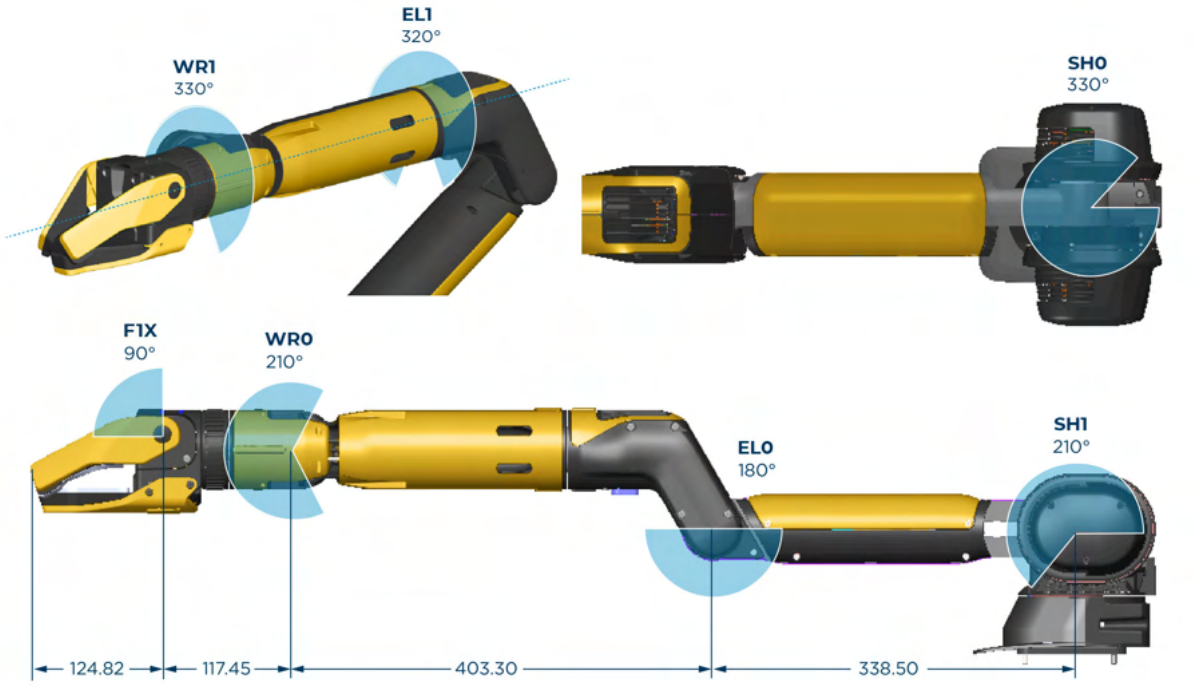
Gripper

Specification	Value
Depth of grip	90 mm
Maximum aperture	175 mm
Peak clamp force (at tip)	130 N
Integrated sensors	Time-of-Flight (ToF) depth sensor, 4K RGB camera
Accessory port	Gigabit Ethernet, 50W power, camera sync (PPS)

REQUIRED READING

For specifications of the base Spot robot, review *Spot Instructions for Use* in the Boston Dynamics Support Center (see Appendix A: Supplemental Information).

1.5.2.1. Joint Specifications



Spot Arm joint designations, range of motion, and length of links (in millimeters).

Joint axis	Description	Range	Max. velocity	Max. torque[1]
SH0	Shoulder rotation	-150°/180°	10 rad/s	90 N·m
SH1	Shoulder pivot	-180°/30°	10 rad/s	90 N·m
EL0	Elbow pivot	0°/180°	10 rad/s	90 N·m
EL1	Elbow rotation	-160°/160°	10 rad/s	23 N·m
WR0	Wrist pivot	-105°/105°	10 rad/s	23 N·m
WR1	Wrist rotation	-165°/165°	10 rad/s	23 N·m
F1X	Gripper pivot	-90°/0°	10 rad/s	11 N·m

[1]Max. torque refers to software limits. All joints except the gripper pivot are also mechanically limited as described in Manipulator Motion.

2. Product Safety Overview

2.1. General Principles

Spot Arm provides general purpose manipulation capability to the base Spot robot. Types of manipulated parts and/or interactions with the environment or equipment are defined when a specific application is determined.

Spot and Spot Arm share the same controller and always use simultaneous motion.

Manipulation on a dynamically balancing robot is a complex operation. Manipulation is affected by physical contact and the exchange of forces with manipulated objects and equipment, which in turn affects the overall balance of the robot.

WARNING

The control of simultaneous motion of Spot and Spot Arm can result in unexpected movements with respect to planned trajectories or previously experienced movements.

Sudden changes in the interaction with the environment or equipment are major sources of large deviations from anticipated or previously experienced movements.

2.2. Intended Use

Spot Arm is intended for general purpose manipulation, imaging, and sensing as part of professional use in either industrial or restricted or controlled environments.

Spot Arm is not intended for collaborative applications involving physical interaction with humans. People can be occasionally present in the same space as Spot for purposes unrelated to Spot operations (see "Bystander" in Key Terminology).

You must complete a risk assessment of Spot Arm manipulation applications to be implemented by users including, but not limited to, tools and parts manipulated, equipment that is part of the application, and safeguards that may be integrated.

Explicitly prohibited uses include:

- Use without performing a risk assessment.
- Underwater and airborne applications.
- Use as a weapon or to enable any weapon.
- Any use as – or enabling the use of – a Certified Medical Device. Access and operation in healthcare facilities subject to limitations.
- Use in personal care, medical treatment or life-critical applications.
- Use in home environments.

- Transportation of persons or animals.
- Transportation of hazardous materials or substances.
- Intentionally harming any person with Spot Arm or any object carried by Spot Arm.
- Use for any illegal purpose.
- Use as a climbing aid.
- Interfering with Spot's sensors so as to impair their functioning, intentionally altering the environmental conditions so as to impair the functioning of Spot's sensors, or intentionally altering the environmental conditions so as to impair Spot's locomotion.

The risk assessment shall consider the entire lifecycle of the Spot and Spot Arm applications, including but not limited to:

- Setting up and commissioning, with particular attention to training activities.
- Regular use, with particular attention to navigation operations.
- Maintenance and troubleshooting.

2.3. Modes of Operation

Spot and Spot Arm share the same controller. Spot Arm is always operated in the same mode as Spot.

- Manual: Direct control of Spot and Spot Arm by displaying images from the robot's cameras on a remote controller (see Remote Controllers). Manual mode is also used when recording Autowalk missions.
- Automatic: Spot and Spot Arm operate automatically to replay an Autowalk mission. See Spot Arm Behavior During Autowalk Missions.

REQUIRED READING

For details on Spot Arm's modes of operation, review *Spot Instructions for Use* in the Boston Dynamics Support Center (see Appendix A: Supplemental Information).

CAUTION

Spot and Spot Arm shall always be remotely controlled by properly trained operators. Spot and Spot Arm shall always execute automatic operations configured or programmed by a trained professional.

Failure to properly verify programmed applications may result in unexpected hazards during operations.

The frequency and duration of Spot and Spot Arm operations in either manual or automatic modes varies greatly depending on the final application Spot is used for.

For example, applications including routine inspections of industrial assets can be configured along a route in manual mode and then be repeated and completed largely in automatic mode, including

automatic operation of Spot Arm to deploy the gripper camera for imaging or to manipulate a door during navigation. While operating in automatic mode, Spot is expected to encounter bystanders not involved in its operations for very brief moments along routes. While operating in manual mode, interactions with bystanders are expected to be longer, although limited in time, and may include people attending to their own tasks in the operating environment.

A complete analysis (see Risk Assessment) of foreseeable exposure to Spot must be done before commissioning any final application.

2.4. General Safety Features

Spot and Spot Arm share the same controller. Velocity limits and stopping functions are controlled by Spot.

CAUTION

Spot's obstacle detection and avoidance features apply only to the navigation of the base robot (body and legs). These features will not prevent Spot Arm from colliding with objects in the environment during arm operation or when navigating Spot with the arm deployed.

REQUIRED READING

For an overview of Spot's safety features, review *Spot Instructions for Use* in the Boston Dynamics Support Center (see Appendix A: Supplemental Information).

2.5. Stopping Functions

2.5.1. Operational Stop in Manual Mode

Spot Arm shares a controller with Spot. Any policy or command that would stop or de-energize Spot will simultaneously stop or de-energize Spot Arm. See Remote Controllers and Manipulation Mode under "Manual Stop Using the Tablet Controller".

2.5.2. Safety-Related Stop

Spot Arm implements the same protective and emergency stop functions of Spot. Spot Arm will execute an uncontrolled stop (IEC 60204-1 Cat 0 stop), resulting in an immediate collapse of the manipulator part in order to avoid additional hazards (flailing of a stiff arm or falling on locked arm joints in ways that could prevent the robot from reaching a stable de-energized state, or that could prolong the time and distance needed to reach such a state).

On flat ground, Spot with Spot Arm will lower its body and the manipulator will collapse downward from its current position (stowed or deployed).

WARNING

When motors are de-energized, Spot will lose its ability to stand and balance. Spot Arm will not keep its joints locked.

On inclined surfaces or stairs, Spot with Spot Arm may tip over.

The maximum estimated stopping distances are illustrated in Stopping Time and Distance.

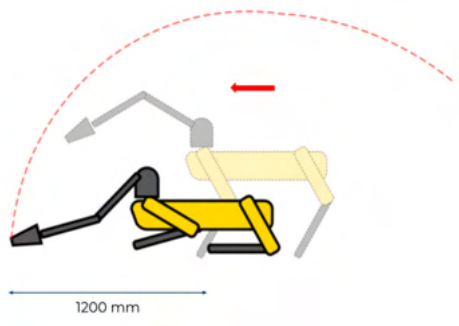
2.5.3. Stopping Time and Distance

The maximum response time for the stopping function is 200 ms.

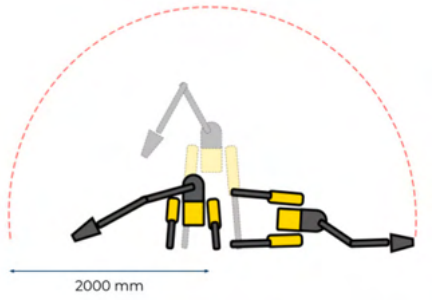
After a stop, Spot with Spot Arm is de-energized (all motors powered off). The configuration of Spot legs and Spot Arm is not predictable, as it depends on the dynamics of the stop which are greatly influenced by the pose of Spot with Spot Arm at the time of the stop.

An uncontrolled stop may involve a displacement of the arm up to its full length in any direction from the robot's body. Operators should assume the minimum distances for completing a stop are as follows:

Direction	Minimum distance
Front and rear	1200 mm
Lateral	2000 mm



Minimum stopping distance (front and rear).



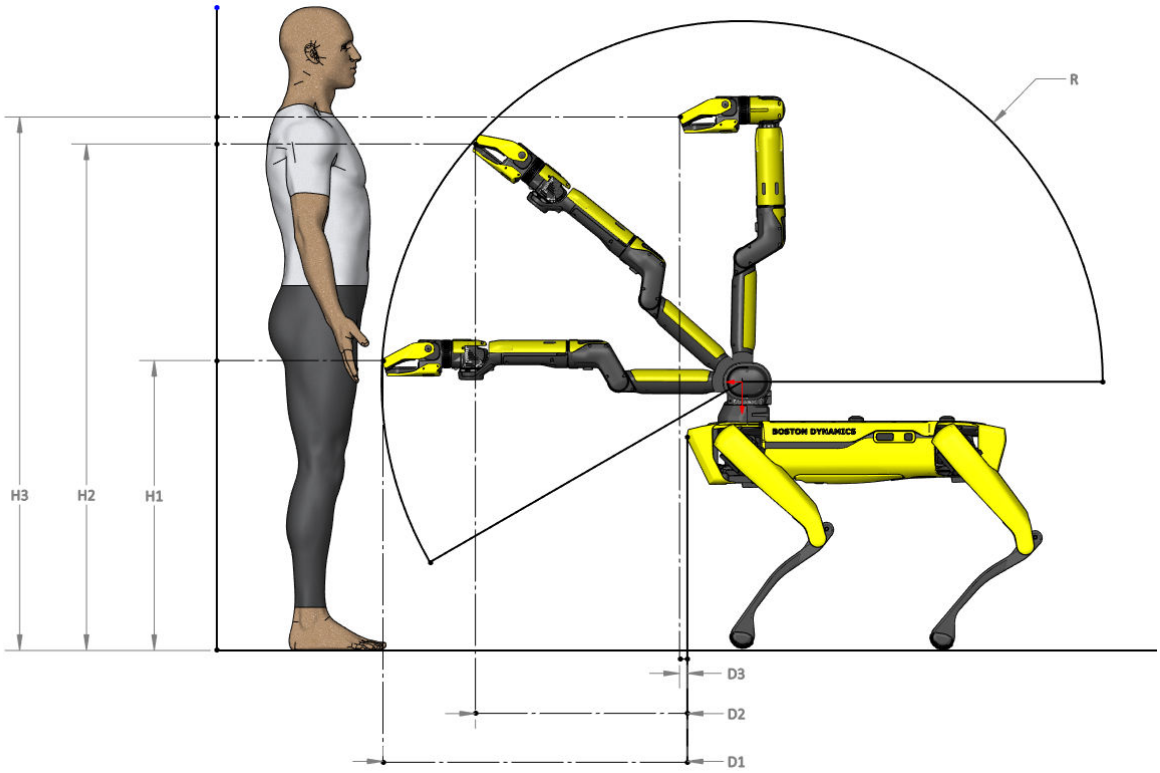
Minimum stopping distance (lateral).

2.6. Manipulator Motion

2.6.1. Spot Arm Workspace

The working space of Spot Arm is determined by the volume used to plan and execute a trajectory, which depends on the combination of the following factors:

- Volume where the manipulator can move (maximum space of the manipulator) as determined by the range of motion of the joints.
- Rotation and translation displacement of the Spot base, which moves the entire manipulator space.



Spot Arm workspace dimensions.

The principle figures for estimating the extension of the Spot Arm workspace are reported in the following table.

Dimension	Description	Typical value/range	Notes
R	Maximum extension of Spot Arm	985 mm	At the tip of the gripper
H1	Height of Spot with Spot Arm at maximum horizontal extension	1110 mm +/- 160 mm	Variable depending on the height and pitch/roll of the Spot base

Dimension	Description	Typical value/range	Notes
D1	Extension of Spot Arm beyond the footprint of Spot, at maximum horizontal extension	850 mm	Furthest point forward
H2	Height of Spot with Spot Arm in 45° configuration	1480 mm +/- 160 mm	Variable depending on the height and pitch/roll of the Spot base
D2	Extension of Spot Arm beyond the footprint of Spot in 45° configuration	580 mm	Combination of moderate extension and high elevation
H3	Height of Spot in vertical configuration	1560 mm +/- 160 mm	Variable depending on the height and pitch/roll of the Spot base Gripper is oriented horizontally toward the front of Spot
D3	Extension of Spot Arm beyond the footprint of Spot in vertical configuration	Up to 20 mm	Gripper is oriented horizontally toward the front of Spot

2.6.2. Manipulation Primitives: Arm Positions

Spot Arm has three basic positions that can be activated during operation to quickly reconfigure the arm relative to Spot's body: Stowed, Ready, and Carry.

Spot Arm in the Stowed position.

Spot Arm in the Ready position.

Spot Arm in the Carry position.

2.6.2.1. Stowed Position

In the Stowed position, the shoulder and elbow joints are fully folded. The arm is centered on top of Spot with the elbow joint toward the rear and the gripper overhanging to the front.

Stowed is the default position for Spot Arm when Spot is not actively being operated for manipulation.

2.6.2.2. Ready Position

In the Ready position, the arm is deployed forward with the gripper pointed ahead of Spot. The gripper jaws are open to provide an unobstructed view from the gripper camera.

2.6.2.3. Carry Position

In the Carry position, the arm is deployed forward with the gripper held ahead of and slightly above Spot. The gripper is oriented toward the ground.

2.6.3. Torque Limitation

The torque on each joint of Spot Arm is limited by software as indicated in Specifications. Torque is also limited mechanically by clutch mechanisms for all joints except the gripper pivot.

Clutch types:

- *SH0, SH1, EL0* – Friction
- *EL1, WR0, WR1* – Ball detent

Exceeding the maximum torque will make a joint slip until a hardstop is reached. Motors will quickly reduce power to prevent overloading the slipping joint.

As a result, the maximum force on potential static contacts is always limited and its value depends on the configuration of the manipulator.

NOTICE

Spot Arm has an additional software force limiter to reduce the external forces to Spot's body (through the manipulator) that may cause loss of balance. This is not a safety function.

2.6.4. Velocity Limitation

When operating Spot Arm directly, the end-effector's maximum speed is adjustable up to 0.75 m/s. To switch between the following maximum speed settings, see Operate Arm.

Speed setting	Maximum velocity
Fast	0.75 m/s
Med (default)	0.50 m/s
Slow	0.25 m/s

CAUTION

Changes to speed settings take effect immediately. The end-effector may change speed while in motion.

Speed settings limit the maximum linear velocity that can be requested by the end-effector. When an operator commands a direct motion of the end-effector, the actual motion and speed are determined by the coordinated motion of all Spot Arm joints and segments plus stability adjustments made by the base robot. The actual speed of the end-effector or other arm segments can be briefly higher or lower than the requested speed based on a combination of factors including:

- The current speed setting.
- Variable inputs from manipulation controls, such as the amount of tilt applied to the joysticks on the tablet controller.
- Commanded motions of the end-effector that approach the limits of joint range-of-motion and and require a sudden realignment of the position of one or more arm segments to continue the motion.
- A sudden removal of resistance against a commanded motion, such as a door that is unexpectedly opened from the inside while the end-effector is exerting force on the exterior.
- Disturbances that cause Spot to move suddenly so as to maintain balance.
- Disturbances that result in a fall, during which the end-effector and/or other arm segments may briefly exceed the maximum speed before being de-energized and/or coming to rest.

In general, alterations that increase speed are likely to be limited to one or several arm segments rather than the entire assembly.

2.7. Risk Assessment

Boston Dynamics has assessed and evaluated risks within the intended use of Spot and Spot Arm (see Intended Use). Review also Declarations and Marking for compliance with regulations, if applicable.

The following paragraphs provide guidance about the additional risk assessment that you must complete before using Spot and Spot Arm. Refer to ISO 12100 for the general methodology of risk assessment.

Risks are the transformation of potential hazards into actual harms. To estimate risks it is necessary to combine a measure of:

- The severity of the effect of hazards.
- The occurrence of hazards (how often, how likely, how predictably, how well-anticipated).

2.7.1. Before starting

You must complete your own risk assessment according to your knowledge of the manipulation application, considering:

1. **Intended use**: The set of specific manipulation actions, with particular attention to the parts and equipment manipulated during operations.
2. **Foreseeable misuse**: Anything that does not pertain to the intended use and appears as a form of misconduct. The occurrence of misuses can be estimated to be less likely than intended uses.
3. **Non-task-based interactions**: People can be close to Spot with Spot Arm as a mere result of sharing the same facility. The occurrence of unrelated interactions is uncommon, infrequent, typically not permanent, and rarely known in advance.

4. Role and type of **personnel**.
    a. *Affected*: People can be occasionally present in the same space as Spot with Spot Arm for purposes unrelated to Spot operations. This is the most generic class of exposed people.
    b. *Qualified*: People assigned to operate Spot with Spot Arm (e.g. programming missions, remotely-operated manipulation). The frequency of these tasks depends on the application.
5. **Environment of operation**: Given the physical interaction of Spot Arm with parts and equipment during manipulation operations, the analysis of layouts is essential to estimate the direct and indirect effects of hazards. Potential sources of hazards could originate from cascade events.

    The final environment of Spot Arm applications can significantly alter the conditions for the severity of hazards and alter (normally worsen) the probability of occurrence of failures or hazardous conditions. Important elements for the assessment of the environment include: walking surfaces, slopes, elevated grounds, stairways, lighting, temperature and humidity, presence of condensation, and obstacles.

> **REQUIRED READING**
>
> For an overview of the generic environmental conditions specified for Spot, review *Spot Instructions for Use* in the Boston Dynamics Support Center (see Appendix A: Supplemental Information).

2.7.2. Unintended Contact and Other Hazards Related to Locomotion

Hazards from contact with Spot Arm could be determined by one or more factors specific to manipulation, including but not limited to:

- An accidental direct contact of part of the human body with Spot Arm, during the correct execution of a Spot Arm planned manipulation movement.
- An unintended movement that results from unexpected failures in manipulating objects or from the onset of instability.
- An accidental contact with a part carried by or ejected from Spot Arm.
- An event of loss of stability caused by Spot tripping during a manipulation task.
- An accidental indirect contact of part of the human body with objects (parts, equipment, etc.) manipulated or activated by Spot Arm.

The previous list is not exhaustive, as other significant hazards can be present depending on the particular Spot Arm application.

Because Spot Arm is mounted on and controlled by Spot, hazards during Spot locomotion also apply.

WARNING

Hazards during Spot locomotion happen in the form of unintended behaviors:

- Unpredictable movements of the legs, following a temporary loss of stability and consequent recovery attempts.
- Large deviations from planned and expected paths.
- Sudden accelerations of either the legs or the entire robot as a reaction to external disturbances, like physical impact or the appearance of obstacles.
- Unpredictable movements following a tripping event.
- Sliding or tumbling following a fall or tip-over.
- Any combination of the above.

Always determine the **severity** of potential contacts based on your knowledge of the application, the configuration of Spot Arm, the environment, and the type of exposed persons.

Always determine the *actual* likelihood of the **occurrence** of each potential contact based on your knowledge of the application, the environment, and the type of exposed persons.

2.7.2.1. Considerations for the Severity of Hazards

Each joint of the manipulator has a mechanical torque limitation. External loads due to impacts will make joints slip until an external constraint or hardstop activates to prevent further slips. See Manipulator Motion under "Torque Limitation".

- The actual contact force depends on the foreseeable configurations of the manipulator along a trajectory of potential contact. The torque limit (and slip) is reached by different extensions of Spot Arm and in relation to the overall kinetic energy at the moment of the contact.
- The impact force may depend on both the trajectory of Spot Arm and the walking path of Spot.
- The largest displacements and sweeping volumes occur around the SH0 joint.
- The shape of the point of impact on Spot Arm and/or a part carried during manipulation could determine different effects on a person's body. Spot Arm has no sharp edges, but some small parts could generate higher pressure on body tissues.

Spot Arm has a larger workspace compared to Spot, so regions of a person's upper body could be exposed to contact.

- The workspace of Spot Arm extends approximately 1 meter beyond the footprint of the Spot base.
- Although the human torso and back can be reached, any part above the shoulder line (for an average body size) can hardly be reached by a fully extended Spot Arm. See Manipulator Motion.
- The highest point of reach combines the height of the quadruped robot unit and the elevation angle of the manipulator.
- Pitching of Spot is generally limited to +/- 30° in typical configurations. Pitching can compensate for or increase the total elevation angle of Spot Arm relative to its mounting. This configuration affects the values of H and D dimensions as described in Manipulator Motion under "Spot Arm Workspace".

- Elevation angles higher than 60° will maintain the workspace of Spot Arm very close to the footprint of Spot.
- Spot with Spot Arm is not likely to reach the upper human body for elevation angles that are commonly used for moving Spot Arm with respect to the Spot footprint.

2.7.2.1.1. Additional or Unintended Conditions

Alteration factors for the estimation of severity may include:

- Lateral and rear directions of approach may affect the actual point of impact.
- Unforeseeable, indirect hazards caused by secondary effects (e.g. becoming entangled with and pulling on overhanging equipment).
- Body size and age of the affected person.

2.7.2.2. Considerations for the Occurrence of Hazards

2.7.2.2.1. Frequency and Duration of Exposure

Foreseeable hazardous exposures are limited in time, typically:

- Manipulation is not frequently done while in navigation.
- The deployment of Spot Arm from stowed position occurs for a short period of time.
- Manipulation tasks are usually a subset of missions.
- The fastest movements are correlated with the swing of the manipulator around the vertical axis exiting from the shoulder joint with the manipulator fully extended. This configuration is rarely used for manipulation and locomotion.

Low frequency leads invariably to low occurrence when associated with regular skills and high awareness of affected people.

Alteration factors depending on application:

- Average presence of working personnel up to 25% of the total usage time.
- Shared areas used by many people, increasing the total exposure.
- Duration of Manual mode, with Operators directly and remotely operating Spot Arm for longer tasks.

2.7.2.2.2. Probability of Failure (Lack of Availability)

Spot normally activates its collision avoidance capability. However, obstacle detection and avoidance applies only to the base robot. Objects along the trajectories of the manipulator part are not detected.

Using Spot and Spot Arm outside of Spot's environmental limitations may compromise the availability of obstacle detection or downgrade the performance of sensors in ways that are insufficient to generate complete failures but could determine a delay in the detection of obstacles.

Sudden appearance of obstacles from blind directions decreases the probability that Spot reacts in time to avoid such obstacles.

CAUTION

Downgraded perception may determine irregular, possibly fast, movements in non-travel directions.

2.7.2.2.3. Avoidability of Potential Collisions

When used as intended, Spot and Spot Arm allow for high avoidability:

- Spot and Spot Arm are in general distinctively visible.
- Missions follow very regular and repeatable paths.
- Spot's size makes it possible to easily maintain clearances.
- Standard human walking speed matches the fastest settings and exceeds the default settings of Spot velocity.
- Qualified, but also affected personnel are normally familiar with other Autonomous Mobile Robots (AMRs).
- Spot Arm operators are assumed to have received an initial training and are generally classified as high-skill, resulting in low occurrence of risks. Most Operators assigned to remote manipulation operations may be considered well trained.
- Sudden falls (not anticipated by some progressive instability) or unexpected lateral movements happen only under rare circumstances.
- Accelerations and any change of pattern do not occur in a timeframe shorter than 1 second.

Spot Arm movements may become less expected when:

- A loss of grasp generates instantaneous forces and sudden recovery movements, potentially leading to the loss of stability.
- Spot Arm experiences interference from an overhanging obstacle which is then suddenly released.

Unforseeable conditions that lower the avoidability of hazards are:

- Frequent and combined blind corners and/or cluttered environments, which may result from unanticipated changes in layout.
- Applications in which Spot's main direction of motion and the direction of motion of manipulation are not coordinated.
- Insufficient clearances or wrong estimation of the full workspace necessary for Spot and Spot Arm.
- Changes in the configuration of the manipulated equipment.

2.7.3. Loss of Stability and Falls

Spot stands up and keeps balancing only with active control. Manipulation with Spot Arm determines additional effects on stability due to the dynamics of the arm. Potential interaction with the environment could generate kinematic and dynamic constraints that may determine unintended motion.

REQUIRED READING

For an overview of the risk assessment about stability and the effects of environmental conditions on Spot, review *Spot Instructions for Use* in the Boston Dynamics Support Center (see Appendix A: Supplemental Information).

The likelihood of occurrence of a loss of stability must be estimated based on your knowledge of the following factors:

- When Spot Arm is deployed during Spot locomotion, coordinated movements of Spot Arm and Spot may result in potentially large displacements around the robot's expected trajectory, fast recovery of occasional unbalances, and rapid compensation movements. Such movements are not necessarily an indication of failures or imminent loss of stability.
- When touching objects or equipment, Spot Arm may affect the overall balance of Spot with Spot Arm, which may react with large movements to compensate for external forces or for the onset of imbalance.
- The likelihood of unbalances or eventual instability increases when:
  - Spot Arm manipulates objects or equipment on elevated or inclined terrain.
  - Spot Arm uses very a extended configuration of the manipulator resulting in a large offset of its center of mass.
  - Parts are at the limits of carrying weight (more than 5 kg at more than 500 mm of extension).
  - Any combination of the above.
- Areas of the environment where manipulation occurs are rendered weak, fragile, or unstable by changes in the operational layout (e.g. construction or excavation)
- Areas of the environment where manipulation occurs are movable, tilting, or floating.
- Lubricants or other hazardous or slippery materials that occur in the operational environment and are not detected and resolved by site management.
- Manipulation operations may lead to intended or accidental changes in overhanging obstacles or equipment.
- Undetected damage such as broken pipes, cords, or unstable materials in the operational environment.
- When stop events occur on inclines, Spot and Spot Arm will eventually de-energize but could have passive residual motion under gravity (e.g. downhill slide).

Spot Arm (and Spot, due to the shared controller) will automatically disable motor power in the following cases:

- As a result of a detected failure or a detected fall.
- As a result of a safety-related stopping function forcing a de-energized state.

Spot's legs and Spot Arm will not be locked during and after a motor de-energization.

NOTICE

A random locked configuration of the legs and the manipulator part would likely result in an unbalanced condition for the whole robot.

A random locked configuration of the legs and the manipulator part during a tip-over or fall event would increase the likelihood and severity of accidental impacts with rigid objects.

CAUTION

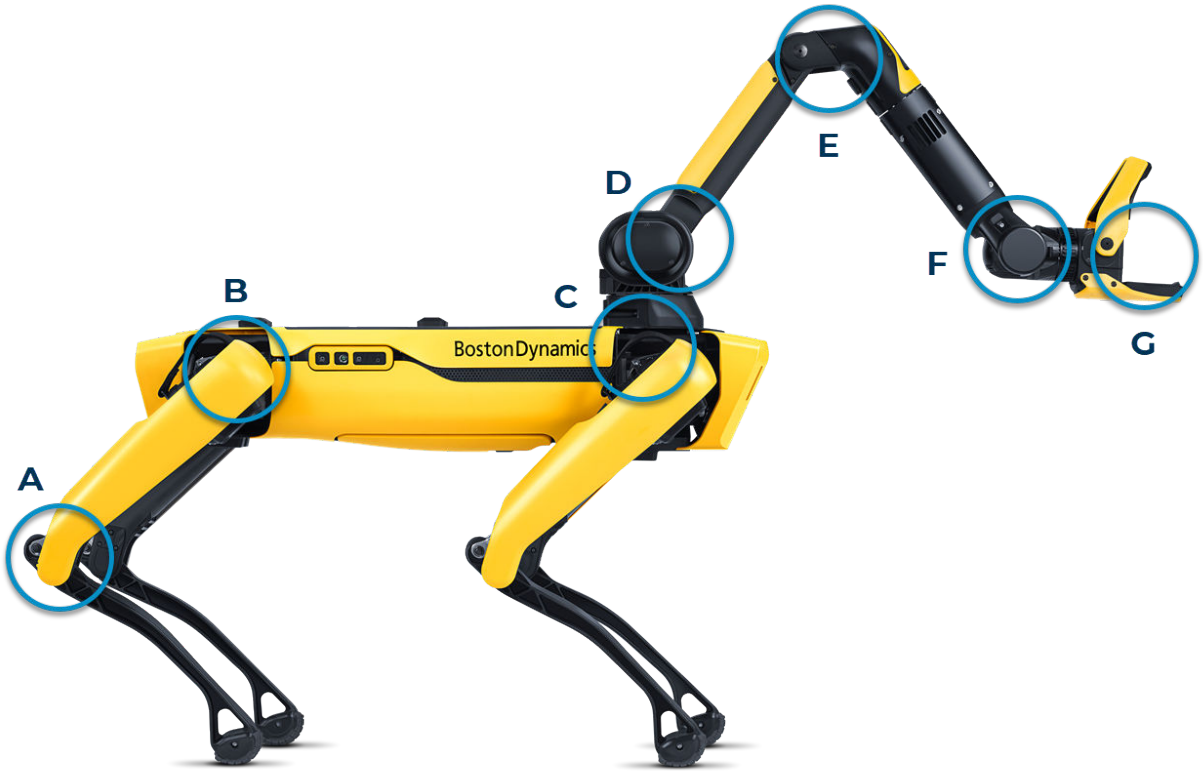
The precise configuration of Spot and Spot Arm during a sudden stop or fall event is entirely unpredictable. The unpredictable actual configuration includes body attitude, configuration of legs, configuration of manipulator, and inclination with respect to the main direction of a flat or inclined ground.

For an example configuration, refer to Stopping Time and Distance.

2.7.4. Pinch Points During Manipulation

Pinch points are present around the joints. Spot Arm could become a pinch point while a person is grasping:

- Spot's knees (A) and hips (B).
- Between the shoulder motors and the top of the front hips (C), specifically when the robot base is rolling laterally.
- Spot Arm's shoulder (D), elbow (E), and wrist (F).
- Spot Arm's gripper (G).



Spot and Spot Arm pinch points.

Pinch points at locations A, B, and C cannot be entirely eliminated without compromising the mobility of the legs, or the ability to walk and maintain balance.

Spot and Spot Arm pinch points are not normally reached in situations other than handling and transportation (while Spot is powered off). When motors are active, there is no foreseeable use that would require access to legs and joints.

When evaluating the hazards associated with Spot Arm pinch points (C - D - E - F - G), estimate the risks considering the following factors:

Ref.	Location	Severity	Occurrence
C	Hip rolling joint	The potential pinching parts are the top of the hip and the SH0/SH1 motor outer case. Some edges can be small but not sharp. No lacerations or cuts are expected. Severity is low.	It is possible to have a pinching event when Spot reaches a very large rolling angle. This configuration seldom occurs in regular and best poses for manipulation. The pinching would affect a person's hand or palm while grabbing the mounting part of Spot Arm or the entire robot body to unduly interfere with balancing while Spot is powered (misuse). Fingers would have easy escape from such situations. Overall occurrence is low.
D - E - F	Manipulator joints	Some edges can be sharp. Minor lacerations or cuts may occur. Severity is medium.	Pinch points along the manipulator's joints are most likely accessible in powered-off conditions, like during maintenance and handling. During powered manipulation it is unlikely that someone would reach into the manipulator space (misuse). Overall occurrence is low.
E	Manipulator elbow	A potential pinch point is created when an additional attachment is mounted on Spot at the rear position, where parts may be close to Spot Arm's elbow. The back of Spot Arm's elbow has no sharp edges, but the type and shape of attachments must be evaluated.	Pinch points along the manipulator's joints are most likely accessible in powered-off conditions, like during maintenance and handling. During powered manipulation it is unlikely that someone would reach into the manipulator space (misuse). Overall occurrence is low.
G	Gripper	Pinch points are determined by the size and geometry of manipulated parts.	During powered manipulation it is unlikely that someone would interfere with the manipulator, the gripper, or the manipulated objects (misuse). Overall occurrence is low.

WARNING

Do not try to recover Spot or Spot Arm by grasping or holding up any of their parts during an apparent loss of stability.

2.8. EM Radiation Considerations

Spot with Spot Arm meets the requirements for unintentional radiators according to electromagnetic compatibility (EMC) standards related to heavy industrial environments (IEC 61000-6-4) and is able to withstand EM disturbances typically found in industrial environments (immunity) within standardized limits.

Test	Level (IEC 61000-6-2)
ESD	+/- 4 KV direct contact, +/- 8 KV air discharge
RF Immunity	10 V/m 80 - 1000 MHz, 3 V/m 1 - 6 GHz

WARNING

Using Spot with Spot Arm in environments with exceptionally high EM disturbances, or integrating high-emission attachments, may result in unexpected behavior from Spot and/or Spot Arm.

2.9. Laser

Spot with Spot Arm contains the following camera systems:

- Five stereo camera systems on the base robot that contain a Class 1 laser projection system.
- One camera system inside the gripper that contains a Class 1 laser projection system.

This product is classified as a Class 1 Laser Product under the EN/IEC 60825-1, Edition 2 (2007) and Edition 3 (2014).

CAUTION

Do not tamper with or make adjustments to any of Spot's or Spot Arm's laser components. Doing so may result in hazardous radiation exposure. Use of controls or adjustments or performance of procedures other than those specified herein may also result in hazardous radiation exposure.

2.10. General Warnings

WARNING

- Do not try to troubleshoot manipulation failures or malfunctions by touching the manipulator part.
- Do not attempt to access the gripper when motors are powered on.
- Do not attempt to manually intervene to help Spot with Spot Arm balance by touching the base or the manipulator.
- Make sure that there is sufficient clearance during training and setup to avoid contact with people and objects or fixtures due to unexpected movements.
- Do not stay on either side of Spot with Spot Arm during operations.

3. Transport, Handling, and Storage

3.1. Transport

Spot with Spot Arm is transported in a customized case designed exclusively for Spot with Spot Arm and its accessories. The Spot battery and charger, attachments, and other equipment are transported separately and in their own specially designed cases where applicable.

NOTICE

Do not discard the case after removing Spot with Spot Arm and its accessories. The case is designed for transporting Spot with Spot Arm and its accessories, and for returning them to Boston Dynamics for service when necessary.

3.1.1. Robot Shipping Case Specifications

The robot shipping case holds the Spot with Spot Arm robot and the Spot tablet controller.

Specification	Value
Length	1060 mm
Width	552 mm
Height	378 mm
Empty case weight	19.3 kg
Combined weight (case and robot)	55.7 kg

3.1.2. Power Supply Shipping Case Specifications

The Spot Power Supply shipping case holds the charger and up to two batteries.

Specification	Value
Length	559 mm
Width	432 mm
Height	432 mm
Empty case weight	9.2 kg
Combined weight (case, charger, and one battery)	18.1 kg

Specification	Value
Combined weight (case, charger, and two batteries)	22.7 kg

3.2. Safe Handling

REQUIRED READING

Before handling or lifting Spot with Spot Arm, review *Spot Instructions for Use* in the Boston Dynamics Support Center (see Appendix A: Supplemental Information).

Handling Spot with Spot Arm is subject to the same safety guidelines and procedures as handling the base robot, with the addition of the following:

WARNING

Before lifting Spot with Spot Arm, the manipulator must be in the Stowed position.

During lifting:

- The manipulator may move out of the Stowed position if Spot with Spot Arm is tilted or jostled.
- A potential pinch point may be created between the shoulder motors and the top of the front hips if Spot with Spot Arm rolled laterally, which could affect a person's hands while grasping the handles. See Pinch Points During Manipulation.
- Do not attempt to lift Spot with Spot Arm by grasping any part of the manipulator. Only lift Spot with Spot Arm by the handles.

CAUTION

Only handle the manipulator by grasping the arm segments. Never grasp the joints. See Pinch Points During Manipulation.

During handling, the manipulator's joints are loose and may swing freely. For tilting or rolling movements such as turning Spot with Spot Arm onto its side, it may be helpful for a second person to support the manipulator to prevent unintended motion.

3.2.1. Boxing and Unboxing

Spot with Spot Arm ships with the manipulator in a configuration that in unsuitable for lifting. Before removing Spot with Spot Arm from its case, the manipulator must be repositioned into the Stow pose.

To unbox Spot with Spot Arm:

1. Open the case. Remove the foam bridge across the center.
2. Raise the arm so that it is fully vertically extended.
3. While holding the gripper in place, grasp the forearm between the wrist and elbow joints. Twist the forearm counterclockwise 45 degrees.
4. While supporting the forearm and gripper, grasp the upper arm between the elbow and shoulder joint. Twist the entire arm clockwise 180 degrees, rotating around the base shoulder joint.
5. Lower the arm to the Stowed pose, allowing the shoulder and elbow joints to fold in opposite directions. The back of the elbow should be pointing toward the rear of Spot and the gripper should be overhanging to the front.
6. With one person at the front and one person at the rear, grasp the handles at each of Spot's hips and lift Spot with Spot Arm out of the case.

To box Spot with Spot Arm:

1. Start with Spot fully powered off in the sit pose and the arm in the stowed position.
2. With one person at the front and one person at the rear, grasp the handles at each of Spot's hips and lift Spot with Spot Arm into the case.
3. Raise the arm so that it is fully vertically extended.
4. While supporting the forearm and gripper, grasp the upper arm between the elbow and shoulder joint. Twist the entire arm counterclockwise 180 degrees, rotating around the base shoulder joint.
5. While holding the gripper in place, grasp the forearm between the wrist and elbow joints. Twist the forearm clockwise 45 degrees.
6. Lower the arm so that it lays flat on top of Spot along Spot's midline. The gripper should be overhanging to the rear.
7. Insert the foam bridge through the gap between the elbow joint and the top of Spot.
8. Close and securely latch the case.

3.2.2. Personal Protective Equipment (PPE)

While handling Spot with Spot Arm, it is recommended to wear safety footwear. Check for additional PPE that may be required in the application environment.

3.3. Storage

Spot with Spot Arm is best stored in the case or at a Spot Dock when not in use. Store Spot with Spot Arm in a dry location with temperatures between -40°C and 75°C, with relative humidity between 30% and 70%.

3.3.1. Battery Storage

The Spot Battery should be stored at temperatures between -30°C and 25°C. It is recommended to develop a battery storage and charging safety policy consistent with industry standards and local regulations.

NOTICE

Always remove the battery when Spot is not in use unless Spot is connected to the Spot Power Supply or sitting on a powered Spot Dock. Batteries left in Spot while not in use will continue to discharge, even when Spot is powered off. Batteries left in a powered off robot for more than 24 hours may be damaged beyond repair.

CAUTION

When shipping the battery, make sure it has been discharged to a 30% or less State Of Charge (SOC). US and international transportation regulations require that lithium-ion batteries of this size be at no greater than a 30% SOC when shipped, regardless of the shipping method (air, ground, rail, or sea). To determine the SOC of the Spot battery, push the button on the battery and read the led indicators. When the indicator shows 1 bar, it means it has less than 30% SOC.

4. Setup

4.1. Preparation

To set up Spot with Spot Arm, follow the same procedures as for setting up the base Spot robot.

CAUTION

Before setting up or operating Spot with Spot Arm, ensure there is at least 3 meters of clearance around Spot in all directions.

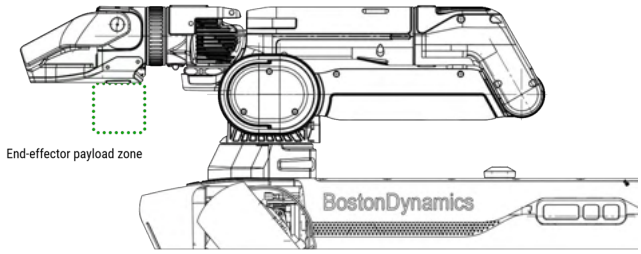
Prepare Spot with Spot Arm on a flat, stable, and clean surface.

REQUIRED READING

For detailed instructions on setting up and commissioning Spot Arm, review *Spot Instructions for Use* in the Boston Dynamics Support Center (see Appendix A: Supplemental Information).

4.2. End-Effector Payload Specifications

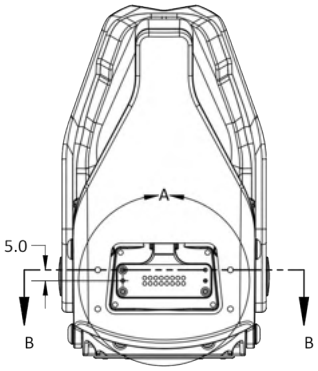
Electrical and mechanical interfaces are available on the Spot Arm for mounting and operating small payloads such as additional cameras or other sensors. Any device attached in this way is considered a Spot attachment and must be included in the risk assessment for your use of Spot and Spot Arm.



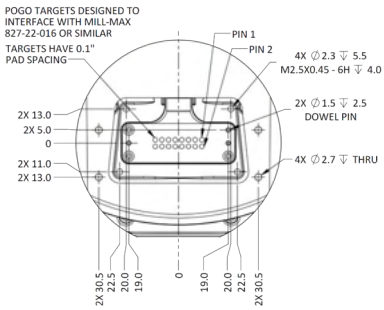
Example end-effector payload zone.

4.2.1. Mounting Interface

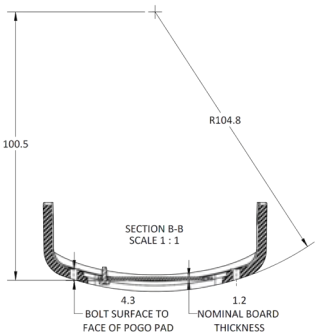
The suggested maximum mass of the end-effector payload is 2.5 kg. Required electrical and mechanical mounting interfaces, as well as suggested overall dimensions and form factor, are shown below.



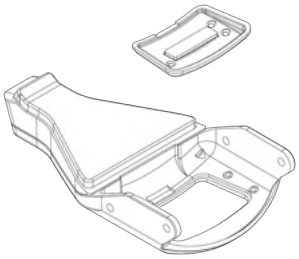
Ventral (underside) view of gripper head.



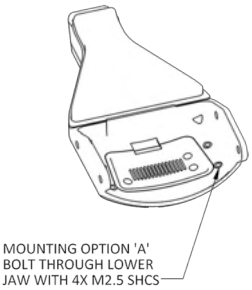
Detailed ventral view of gripper head connector.



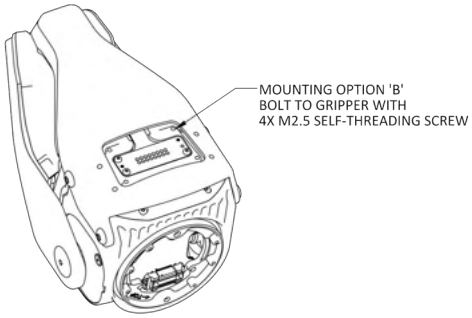
Cross section view of lower jaw assembly.



Lower jaw dorsal view showing cap.



Lower jaw dorsal view: Payload mounting option A.



Gripper head assembly ventral view: Payload mounting option B.

4.2.2. Electrical Connection to the End-Effector Payload

The end-effector payload electrical connection is made through a MILL-MAX 499-10-216-10-008000 Interconnect Target Header on the underside of the end-effector, which will mate to a MILL-MAX 827-22-016-10-002101 Long Stroke Spring-Loaded connector on the payload.

4.2.2.1. Regulated Power

Regulated power is provided at 28V, 50W referenced to DGND. This should be used for most functions of the end-effector payload including imaging systems or embedded computing. Power is enabled 100ms after the robot's internal CPU power is enabled with a 10ms monotonic ramp. This power supply includes a 2.3A current limit, so care should be taken to not exceed this current during spikes in power consumption.

4.2.2.2. Ethernet

The payload connector includes pins to provide 1000Base-T Ethernet for connectivity to the end-effector payload.

NOTICE

Devices plugged into the gripper Ethernet port should have a static IP address on the 192.168.50.x subnet. To avoid conflicts with other payloads, the final octet in the IP address should not be 2, 3, 5, 6, 7, 8, or 9.

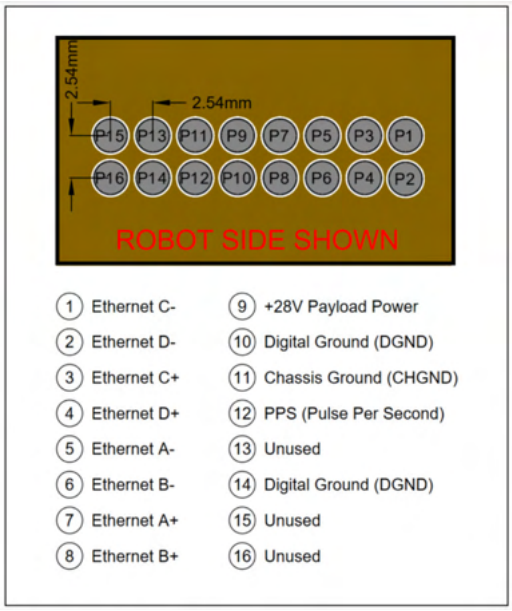
Known unused IP addresses such as 192.168.50.20, 192.168.50.21, or 192.168.50.22 are recommended.

However, if the device requires static port forwarding then a final octet of 7 or 8 may be used provided it does not conflict with other payloads.

4.2.2.3. Pulse-per-Second (PPS)

The robot uses a 5ppm accuracy 1Hz clock to generate a 5V TTL signal pulse. The robot's CPU system times are synchronized using this pulse (PPS). The payload can use PPS for temporal alignment of data provided by the robot, such as IMU information. PPS at the end-effector payload port is present on pin 12 and referenced to DGND (pins 10, 14).

4.2.2.4. Mill-Max Target Pinout and Footprint



Pinout chart for the end-effector payload connector.

Pinout:

- Pin 1 – Ethernet C-
- Pin 2 – Ethernet D-
- Pin 3 – Ethernet C+
- Pin 4 – Ethernet D+
- Pin 5 – Ethernet A-
- Pin 6 – Ethernet B-

- Pin 7 – Ethernet A+
- Pin 8 – Ethernet B+
- Pin 9 – +28V Payload Power
- Pin 10 – Digital Ground (DGND)
- Pin 11 – Chassis Ground (CHGND)
- Pin 12 – Pulse Per Second (PPS)
- Pin 13 – Unused
- Pin 14 – Digital Ground (DGND)
- Pin 15 – Unused
- Pin 16 – Unused

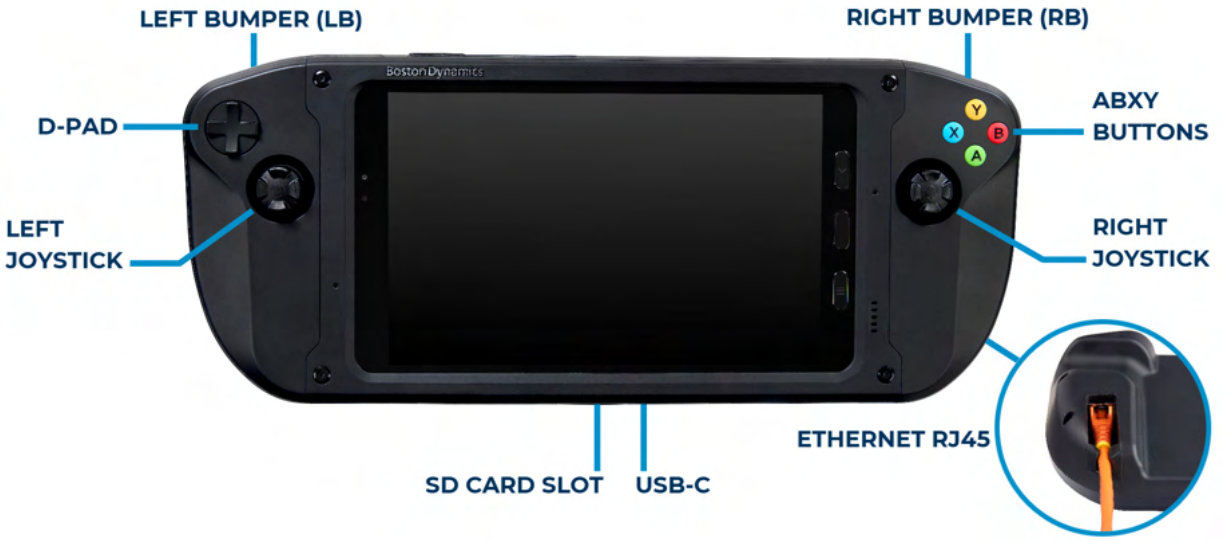
4.2.2.5. End-Effector Payload Grounding

The end-effector payload must maintain ground isolation between three return paths. Three return paths are provided:

- Digital Ground (DGND): This is the reference for digital interfaces such as PPS and is the ground reference for 28V regulated power at the end-effector. It is critical this remain isolated from PGND and CHGND at the end-effector.
- Chassis Ground (CHGND): This is the dedicated ground provided from the robot battery negative terminal to ensure metal housings and cable shields are electrically grounded. Care should be taken to keep this ground isolated at the end-effector and ensure no current should by design complete a circuit by returning to the robot through chassis ground. It is critical this remain isolated from DGND at the end-effector.

4.3. Set Up the Spot Tablet Controller Pro

The Spot Tablet Controller Pro is the combination of the Spot Tablet Controller and a specially-designed joystick housing that adds analog buttons and additional ports. These analog controls are required to drive the Spot Arm.



Buttons and ports on the Spot Controller Pro.

The tablet and joystick housing are shipped separately, and must be assembled before use.

4.3.1. Assemble the Spot Tablet Controller Pro

1. Start with the tablet powered off. Remove any protective case or other attachments from the tablet.

> **NOTICE**
>
> If you intend to use the SD card slot on the Spot Controller Pro for data transfer, remove any SD card from the separate slot on the tablet itself before assembly.
>
> Having an SD card in this slot will cause conflicts with the SD slot on the joystick housing, leading to cards not being recognized or problems mounting and unmounting volumes.

2. Use a Torx T6 screwdriver to remove the four screws securing the bezel to the joystick housing. Remove the bezel and set it aside.

3. Connect the data pass-through USB-C from the joystick housing to the tablet.

4. Place the tablet into the joystick housing starting with the bottom edge, then seat the tablet evenly into the housing.

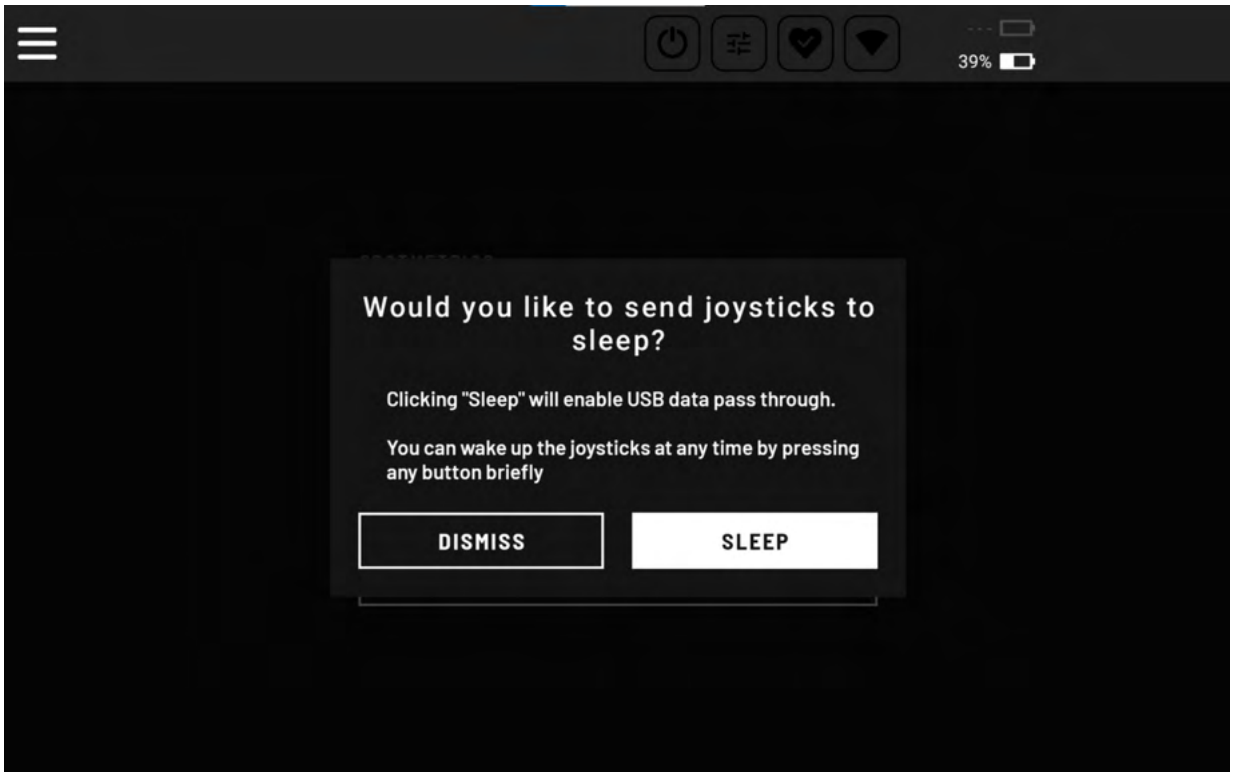
5. Reattach the bezel, ensuring all four screws are fully seated and finger-tight.

WARNING

If the bezel is not installed correctly, the tablet could separate from the joystick housing, potential damaging the controller and causing a loss of control during Spot or Spot Arm operation.

Do not use the Spot Tablet Controller Pro without the bezel.

4.3.2. Sleep and Wake Modes



A prompt to put the Spot Controller Pro into "sleep" mode.

When not in use, the joystick housing enters "sleep" mode to conserve power and allow data transfer to and from the tablet.

When you power on the Spot Tablet Controller Pro, the tablet will power on but the joystick housing will remain in "sleep" mode until you wake it up. In addition, the joysticks will enter “sleep” mode if you do any of the following:

- Connect the tablet controller to a computer via USB-C while you are actively using the Spot App, and then select **SLEEP** when prompted.
- Sign out from Spot by pressing the tablet's back button or selecting ≡ **Menu** > **DISCONNECT** while using the Spot App.
- Turn off the tablet screen, or allow the screen to turn off automatically due to inactivity.

> **NOTICE**
> To avoid disruptions from automatic screen shut-off, increase the screen timeout in the tablet's Android OS settings.

To wake the joysticks:

1. Press and hold any button on the joystick housing to wake it up. The tablet will emit two beeps when it detects the joysticks.

2. When prompted by the Spot App, select **OK** to allow the joysticks to to communicate with the app.

4.3.3. Data transfer

The joystick housing on the Spot Tablet Controller Pro includes a USB-C port and an SD card slot for data transfer to and from the tablet.

4.3.3.1. Transfer Data Over USB-C

The USB-C port on the joystick housing is a direct pass-through to the USB-C port on the tablet itself. However, data can be transferred over USB-C only when the joystick housing is in “sleep” mode.

To transfer data to or from the Spot Tablet Controller Pro over USB-C:

1. Start with the controller powered on and the screen unlocked.
2. Connect one end of a USB-C cable to the port on the bottom of the joystick housing, then connect the other end to your computer.
3. If you are actively using the Spot App, you may be prompted to put the joysticks in sleep mode. Select **SLEEP** to continue.
4. When the Spot Tablet Controller Pro is connected to a computer via USB-C and the joysticks are in sleep mode, you will be prompted to allow data transfer.

> **NOTICE**
> If this prompt does not appear, try turning the tablet screen off and then back on to force the joysticks into sleep mode. The prompt should then appear when you unlock the screen.

4.3.3.2. Transfer Data with an SD Card

The SD card slot on the joystick housing connects to the tablet via the metal contacts along the bottom inside edge of the housing. However, an SD card will not be recognized if the joysticks are in "sleep" mode.

> **NOTICE**
> There is a separate micro SD slot on the tablet itself. Having a micro SD card in this slot will cause conflicts with the SD slot on the joystick housing, leading to cards not being recognized or problems mounting and unmounting volumes.
>
> If you intend to use the SD card slot on the Spot Controller Pro for data transfer, remove any SD card from the separate slot on the tablet itself before assembly.

To transfer data between the Spot Tablet Controller Pro and an SD card:

1. Start with the controller powered on and the screen unlocked.
2. Insert an SD card into the slot on the bottom edge of the joystick housing.

3. Open the tablet's file browser, then wake the joysticks. The SD card's volume will appear as **USB storage 1** and you will be prompted to mount it.

> **NOTICE**
> If this prompt does not appear, try turning the tablet screen off and then back on to force the joysticks into sleep mode. The prompt should then appear when you unlock the screen and wake the joysticks.

4. Mount the volume and transfer files.
5. When finished, unmount the volume before removing the SD card.

5. Use of the Machine

5.1. Remote Controllers

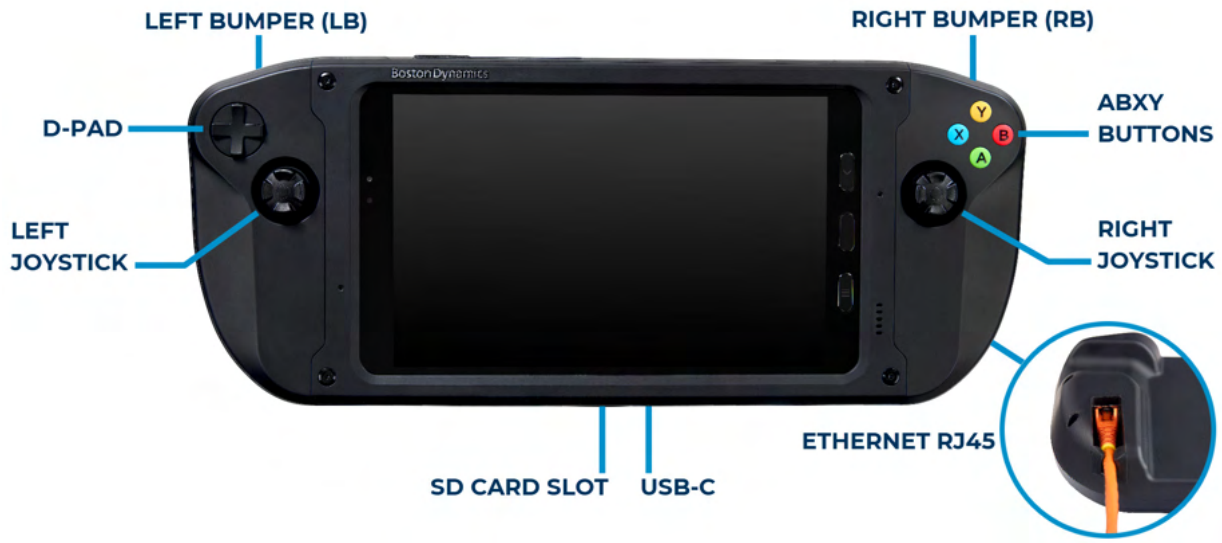
Use of Spot Arm requires the Spot Tablet Controller Pro (the tablet controller that ships with Spot plus an attachment that adds analog joysticks and buttons) or a computer running the Orbit browser application. This document describes the use of the Spot Tablet Controller Pro. For instructions on using Orbit, refer to documentation in the Boston Dynamics Support Center (see Appendix A: Supplemental Information).

Spot with Spot Arm may be compatible with other control devices and software. Only use controllers provided or approved by Boston Dynamics to operate Spot with Spot Arm.

REQUIRED READING

For information and instructions on pairing the Spot Tablet Controller Pro to Spot, review *Spot Instructions for Use* in the Boston Dynamics Support Center (see Appendix A: Supplemental Information).

5.1.1. Analog Controls and Button Combinations



Analog controls and buttons on the Spot Tablet Controller Pro.

The analog controls on the Spot Tablet Controller Pro can be used to drive both Spot and Spot Arm via the Spot App. Spot Arm controls are only active when the Spot App is in Manipulation Mode. Many additional manipulation features are available via the touchscreen and are explained in later sections.

To display button shortcuts in the Spot App, press and hold one of the bumpers (LB or RB) on the top of the joystick housing.

Command	Description	Button combination
Cut Power	Fully de-energizes Spot's and Spot Arm's motors. For more information about stopping functions, refer to Manipulation Mode.	LB + RB + B
Deploy Arm	Moves the arm to the Ready position.	RB + X
Stow Arm	Moves the arm to the Stowed position. Grasped objects must be released before the arm can stow, unless **Item Stowable** is enabled in the manipulator controls menu (see Operate Arm).	RB + B
Reset Arm	Releases any grasp, moves the arm to the Stowed position, deselects **Reach**, and opens the Manipulation Menu.	B B
Grasp / Release	Opens or closes the gripper.	RB + A
Look at Ground	Moves the arm to a forward-facing pose with the gripper camera angled to view the ground in front of Spot.	RB + Y
Reach	Spot stands in place. Joysticks switch to driving Spot Arm.	Y
Sit	Spot lowers its body to the ground. If the gripper is empty or **Item Stowable** is selected in the manipulator controls menu (see Operate Arm), the arm will stow.	X
Walk	Spot stands in place. Joysticks switch to driving Spot.	A
Gripper Fixed in World	When Spot receives a movement command, it will attempt to keep the gripper's position fixed in space by moving its body and arm joints around the gripper.	LB + A
Gripper Fixed in Body	When Spot receives a movement command, it will attempt to maintain the current arm and gripper configuration relative to its own body.	LB + B
Reset Arm Orientation	Aligns the wrist joint with the elbow and orients the gripper to point parallel to the ground.	LB + X
Gripper position	Rotates the gripper position around the shoulder joint.	Left joystick X axis

Command	Description	Button combination
	Moves the gripper position forward/back relative to the shoulder joint.	Left joystick Y axis
	Moves the gripper position up/down.	Right joystick Y axis
Gripper orientation	Adjusts gripper yaw.	LB + Left joystick X axis
	Adjusts gripper pitch.	LB + Left joystick Y axis
	Adjusts gripper roll.	LB + Right joystick X axis

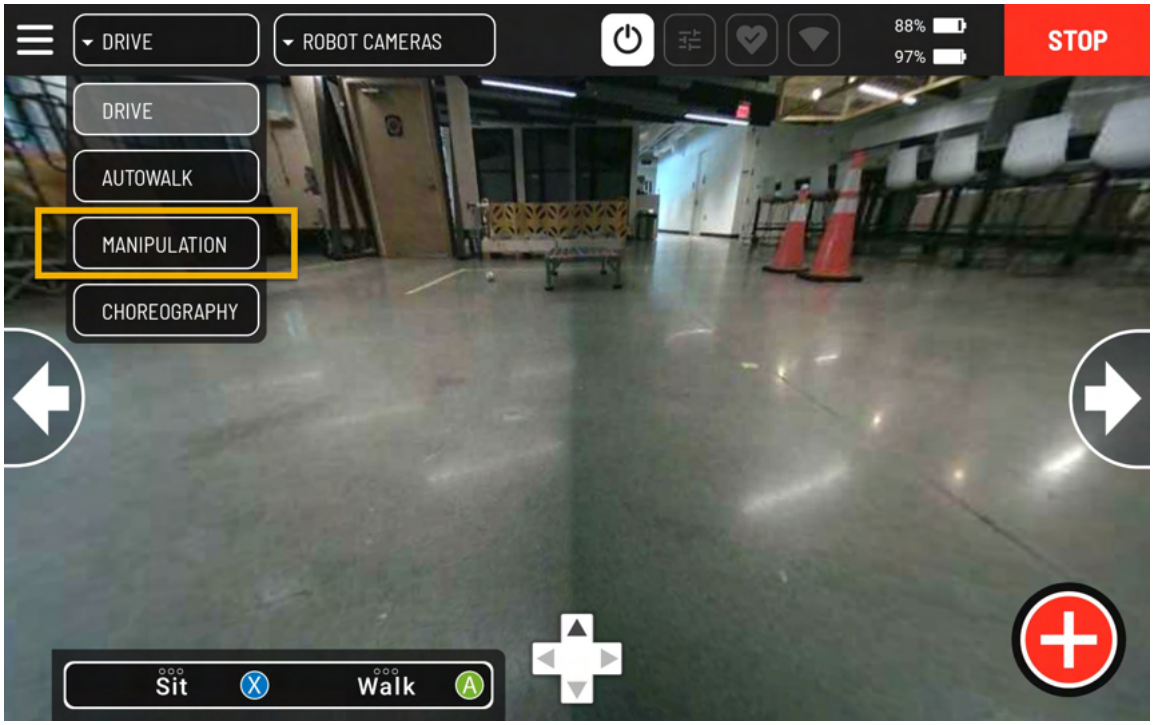
5.2. Manipulation Mode

Manipulation mode is a subset of Manual mode used to control Spot Arm.

5.2.1. Enter and Exit Manipulation Mode

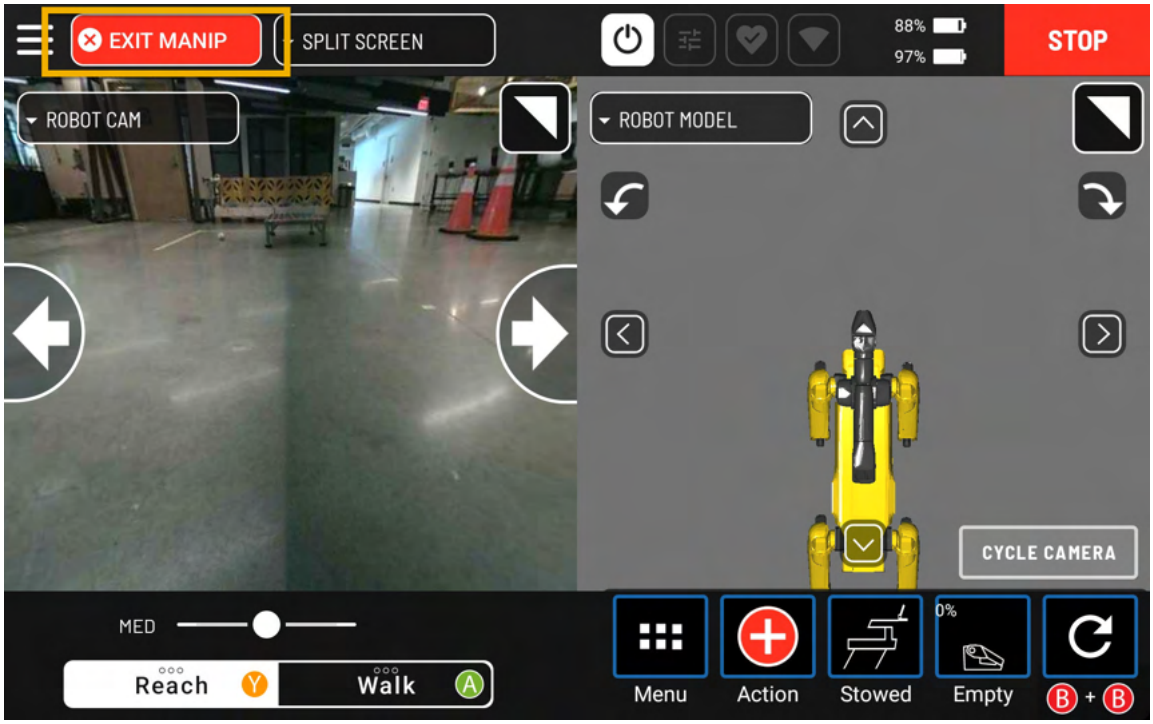
To enter Manipulation mode:

- In the Spot App on the tablet controller, open the Modes dropdown and select **MANIP**.



To exit Manipulation mode:

- Select **EXIT MANIP**.

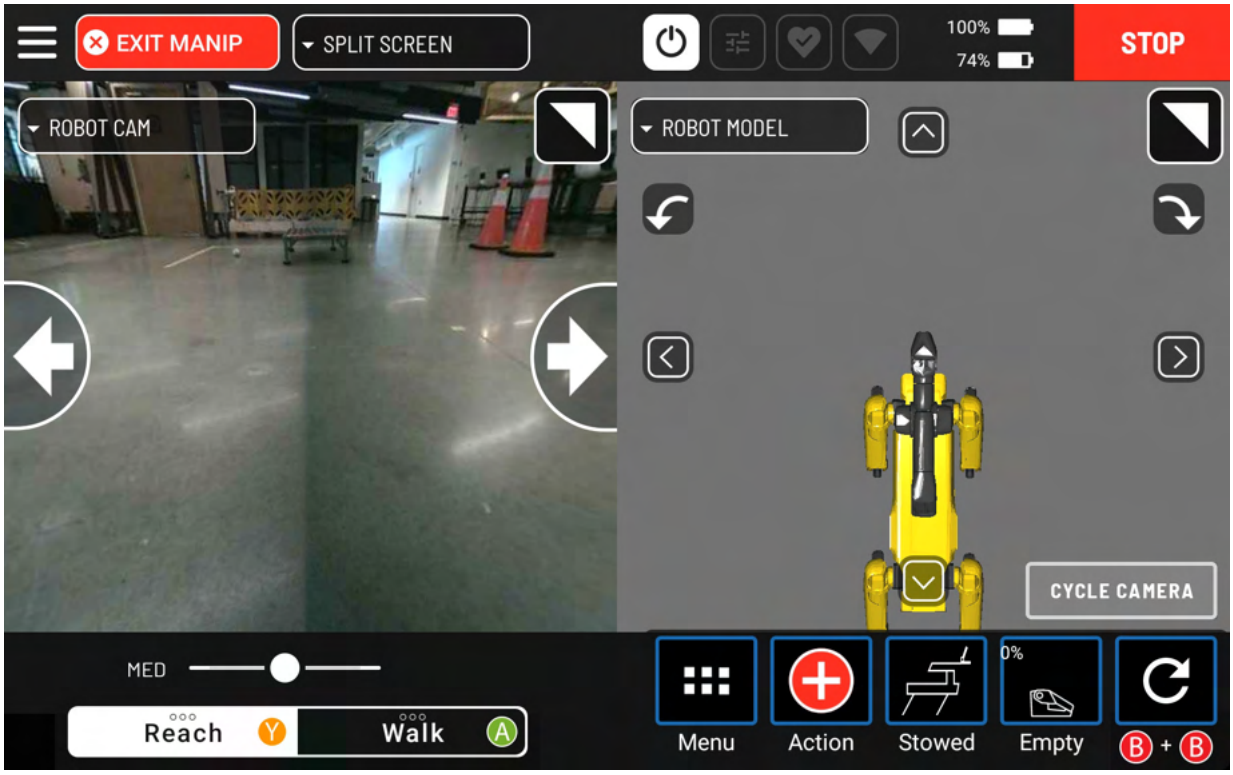


5.2.2. Manual Stop Using the Tablet Controller

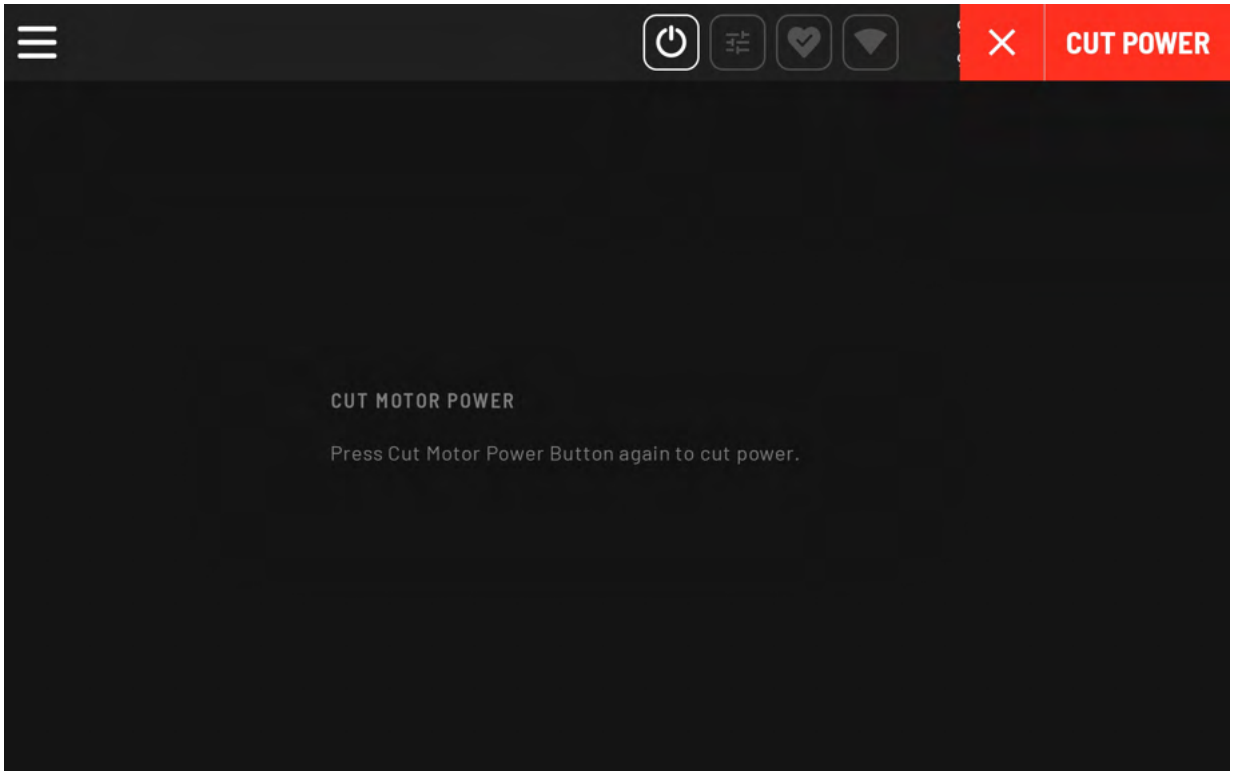
To suspend robot motion while driving Spot or Spot Arm with the tablet controller, select **STOP**. Spot will pause and stand in place, and Spot Arm will hold its position. If Spot is seated, it will remain seated.

To de-energize Spot's and Spot Arm's motors, use either of these methods:

- Press a shortcut combination of physical buttons to **Cut Motor Power**. This shortcut differs depending on tablet configuration and is displayed in the Spot App when you connect to Spot.
- Select **STOP** twice in quick succession. The first selection will suspend robot motion and change the button label to **CUT POWER**. The second selection will de-energize the motors.



*Tablet controller **STOP** button.*



*Tablet controller **CUT POWER** button.*

WARNING

When motors are de-energized:

- Spot will lose its ability to stand and balance. On flat ground, Spot will lower its body. On inclined surfaces or stairs, Spot may tip over.
- Spot Arm's joints will move freely as it collapses.

5.2.3. Reset Spot Arm

At any time during manipulation, you can reset the arm to do all of the following:

- Cancel the current operation.
- Release any grasp, unless **Item Stowable** is set to true in the manipulator controls menu (see Operate Arm).

  CAUTION

  Releasing a grasp does not guarantee that a grasped object will separate from the gripper.

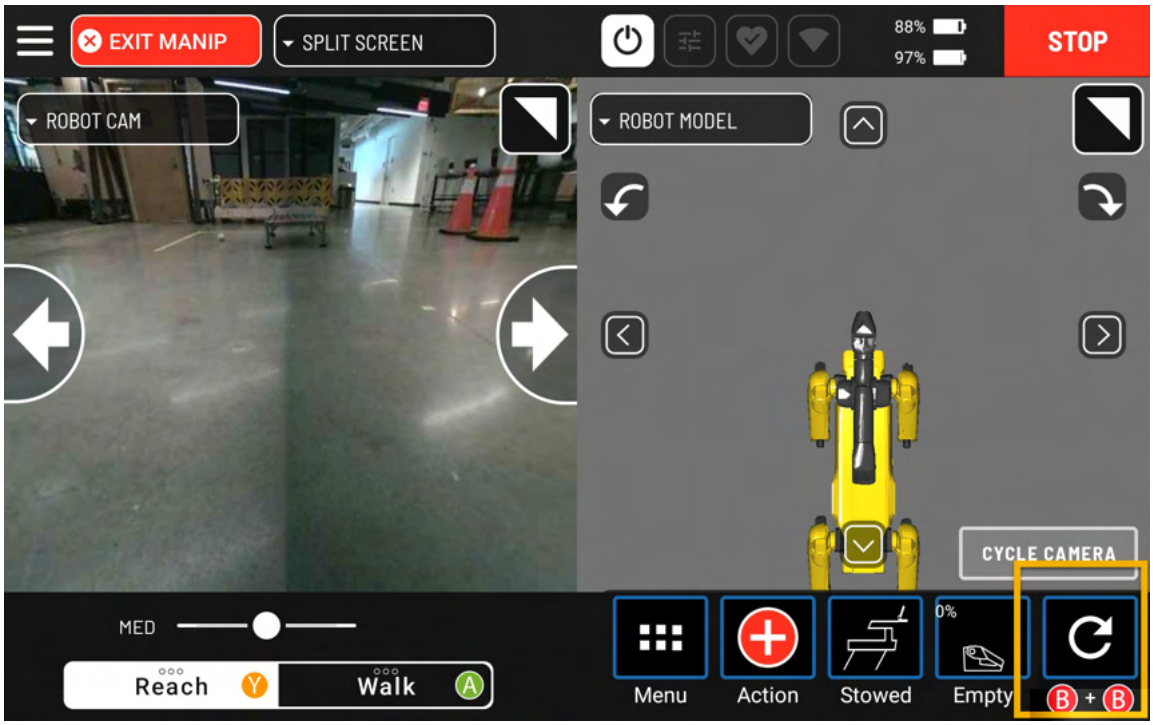
  - The gripper may remain in contact with or close to a fixed object even after releasing it, such that the gripper moves, pushes against, or becomes entangled with the object during subsequent arm movements.
  - Objects may remain balanced on, and soft or pliable objects may deform around, the gripper jaws such that they do not separate from the gripper when a grasp is released. This may cause a mismatch between the gripper's software state (empty) and its actual state (holding an object), which you can correct using the gripper controls menu (see Operate Arm).

    Operating Spot or Spot Arm when the gripper's software state and actual state are mismatched may cause unpredictable behavior.

- Stow the arm.
- Deselect **Reach**.
- Open the Manipulation Menu.

To reset the arm:

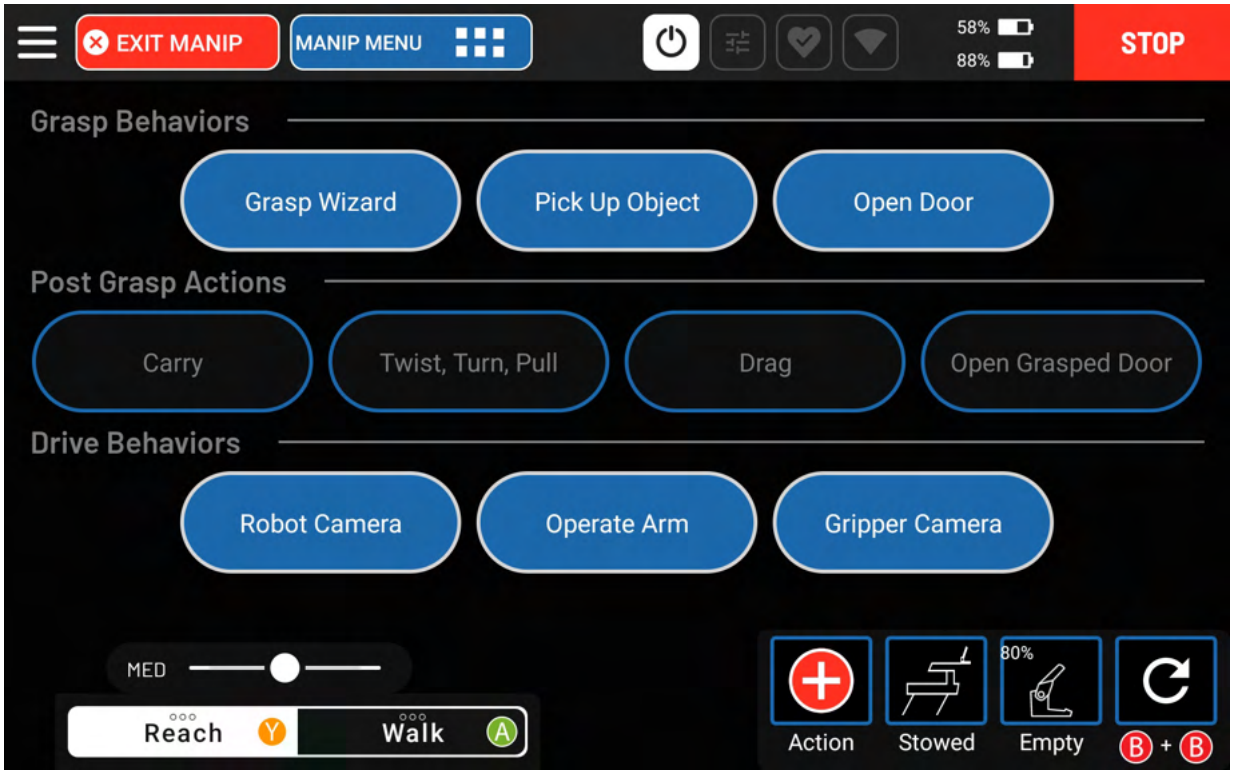
- Press Ⓑ Ⓑ on the joysticks, or select ↻ **Reset** then **Confirm Reset**.



5.2.4. Manipulation Menu

The Manipulation Menu is a collection of interfaces for manually controlling Spot Arm and accomplishing manipulation operations.

The Manipulation Menu is only available in Manipulation mode.



The Manipulation Menu in the Spot App.

> **WARNING**
> Any manipulation operation could result in sudden unintended movements of Spot and Spot Arm, depending on the environmental conditions and the object that is being manipulated.

Grasp Behaviors

Option	Description
Grasp Wizard	Semi-automatically grasp an object by specifying the approach angle, gripper location, and gripper orientation. See Grasping.
Pick Up ObjectPick Up Object	Semi-automatically grasp an object so it can be moved in the environment. See Grasping.
Open Door	Semi-automatically approach and open a door. See Opening Doors.

Post Grasp Actions

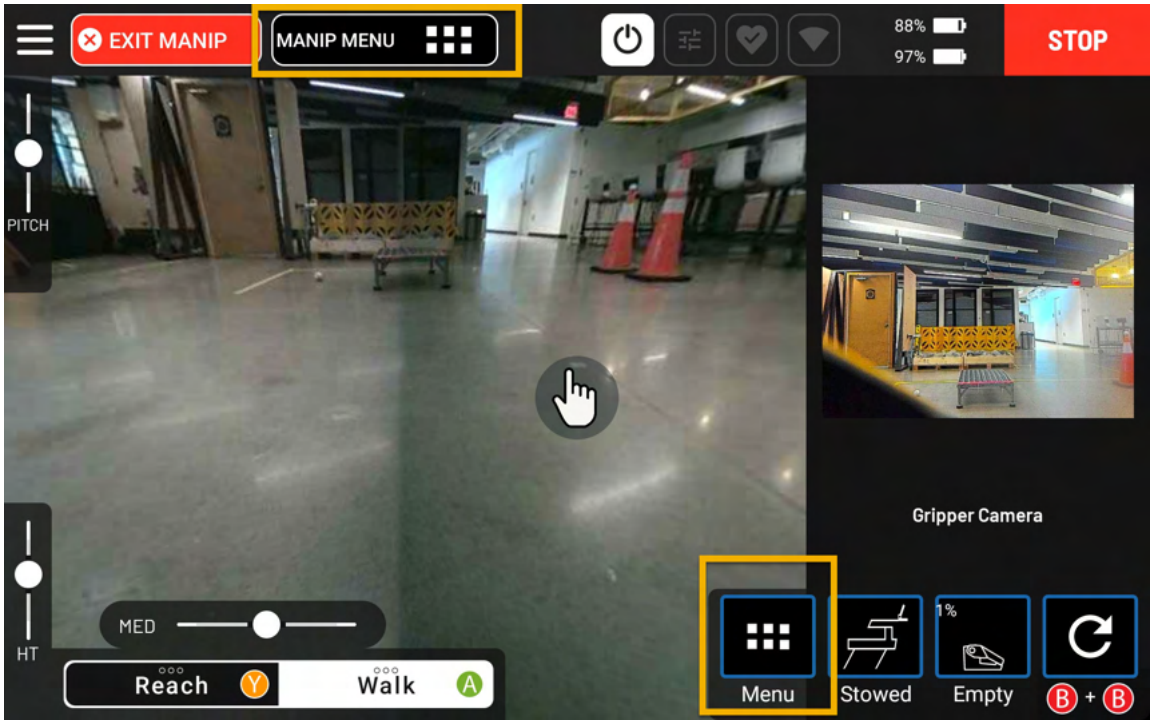
Option	Description
Carry	Lift and hold an object while Spot moves around. See Carrying and Dragging.
Drag	Pull an object from one location to another. See Carrying and Dragging.
Twist, Turn, Pull	Manipulate objects that have limited axes and ranges of movement, such as switches, levers, cranks, valves, wheels, cabinets, and drawers. See Constrained Manipulation.
Open Grasped Door	Semi-automatically open a door that Spot is already grasping. See Opening Doors.

Drive Behaviors

Option	Description
Robot Camera	Switch the tablet view to use Spot's body cameras.
Operate Arm	Manually control Spot Arm. See Operate Arm.
Gripper Camera	Switch the tablet view to use the gripper camera and manually control Spot Arm. See Operate Arm.

To access the Manipulation Menu:

- When in Manipulation mode, select **MANIP MENU** or **Menu**.



5.3. Grasping

Grasping is the starting point for most manipulation tasks with Spot Arm. Grasps can be achieved through direct control of the arm and gripper, or by using semi-automatic features such as the Grasp Wizard, Pick Up Object, and Open Door.

For best results, approach the object to be grasped straight-on. Grasping works best when the object is located directly in front of Spot and at or below Spot's body height.

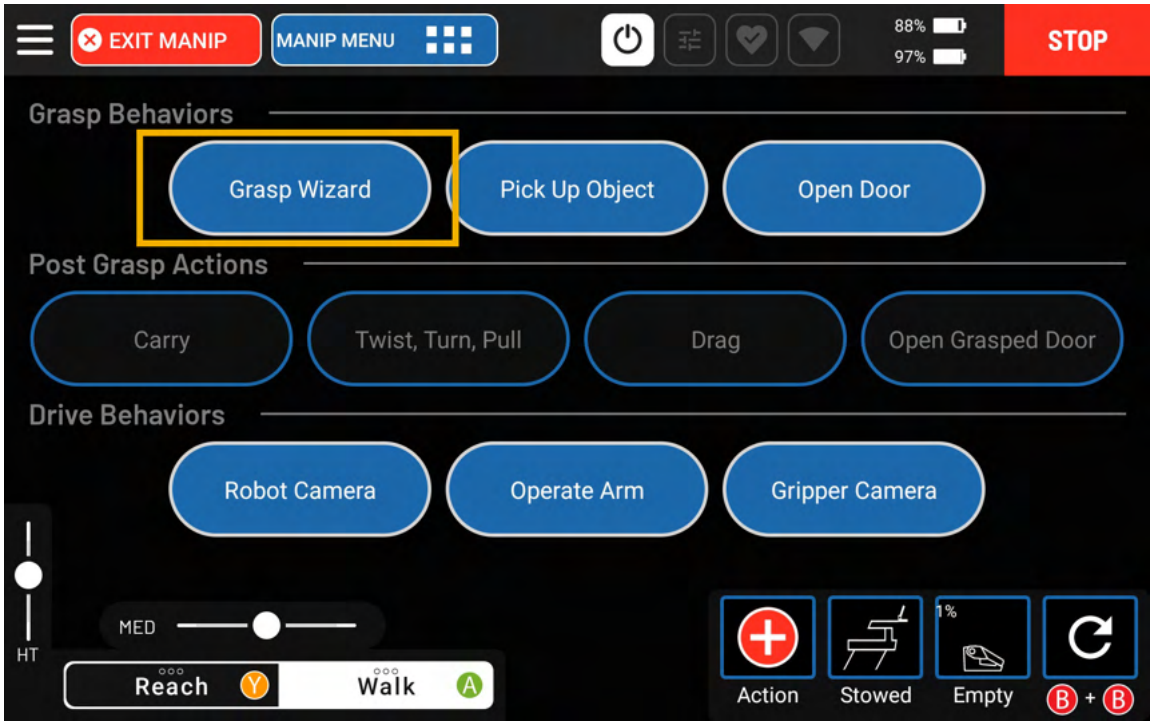
5.3.1. Grasp Wizard

Use the Grasp Wizard to semi-automatically grasp an object by specifying the approach angle, gripper location, and gripper orientation.

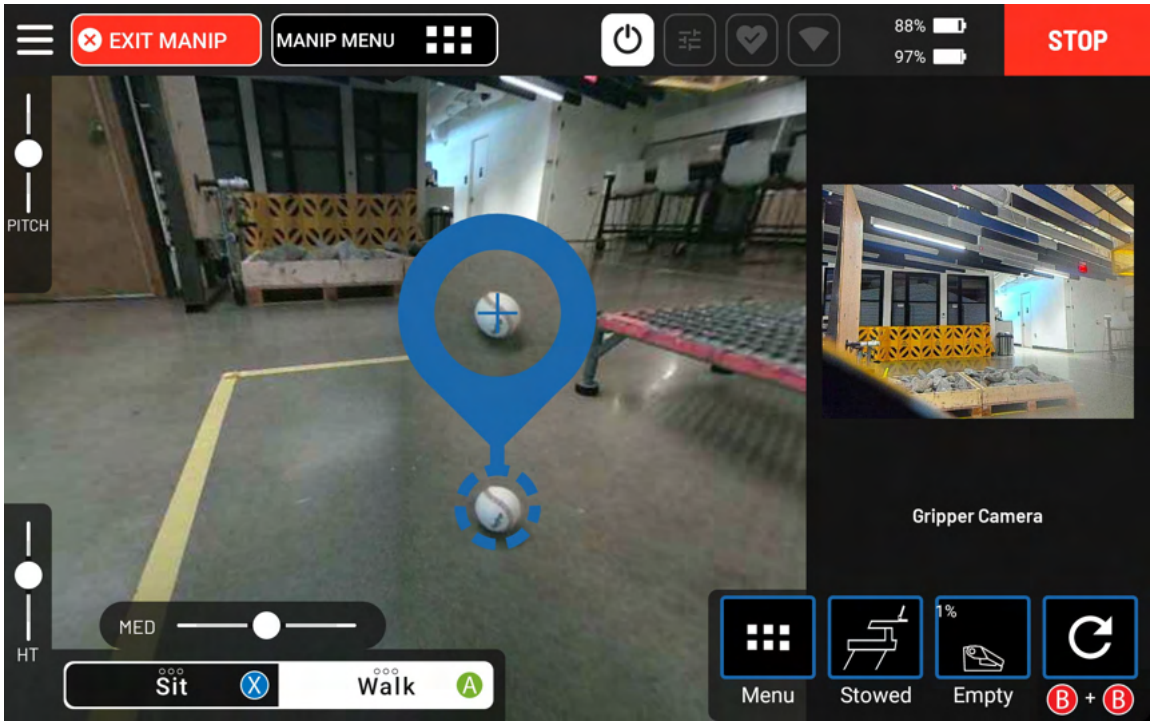
A firm grasp is required to successfully open doors, carry or drag objects, and accomplish other manipulation tasks.

To use the Grasp Wizard:

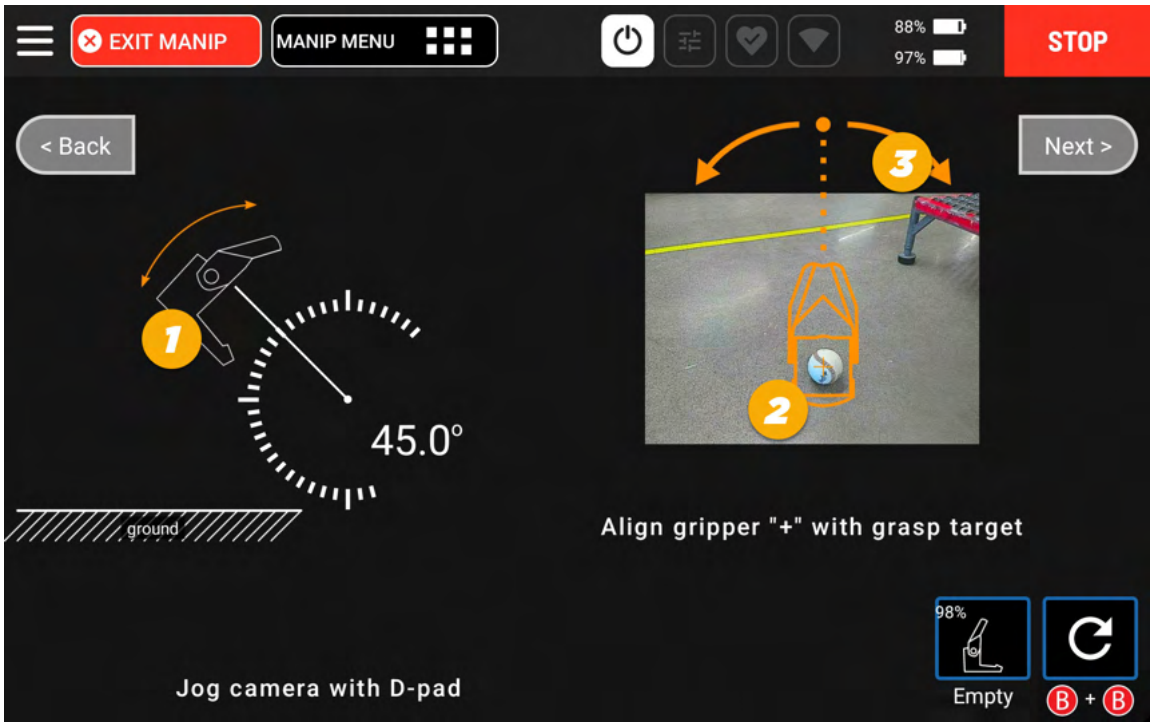
1. On the tablet controller, open the Manipulation Menu and select **Grasp Wizard**.



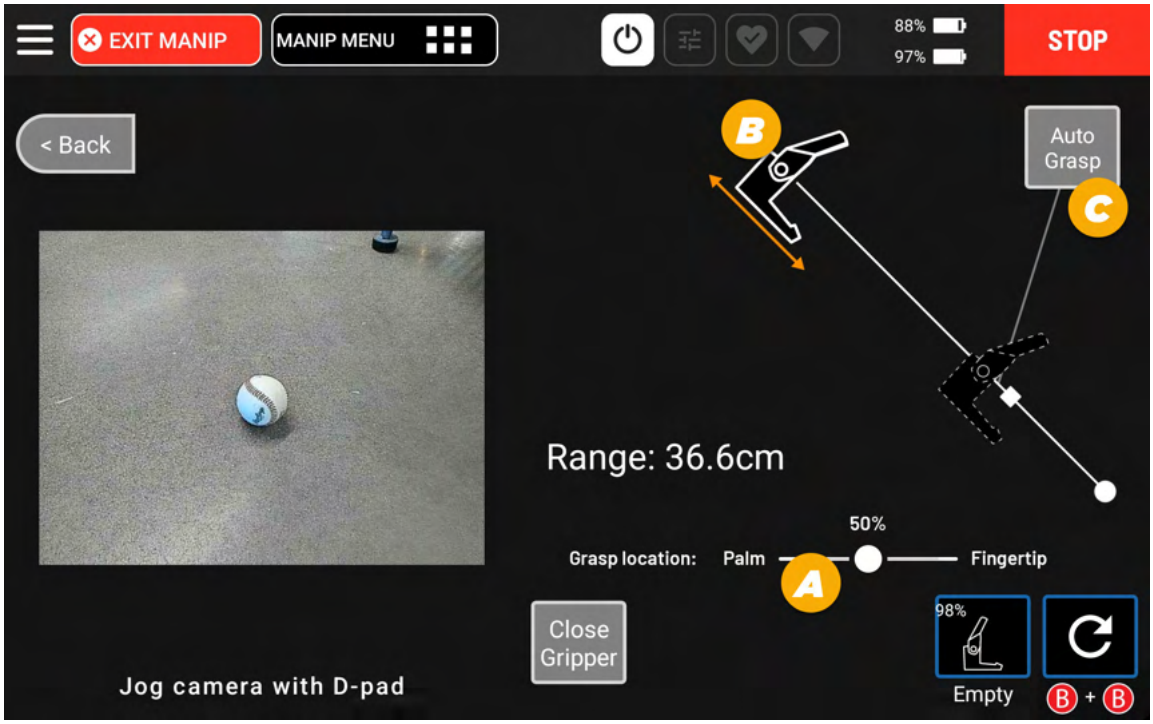
2. Touch-and-drag to select the object you want to grasp.



3. Touch-and-drag to adjust the approach angle (1), gripper target (2), and gripper orientation (3), then select **Next**.

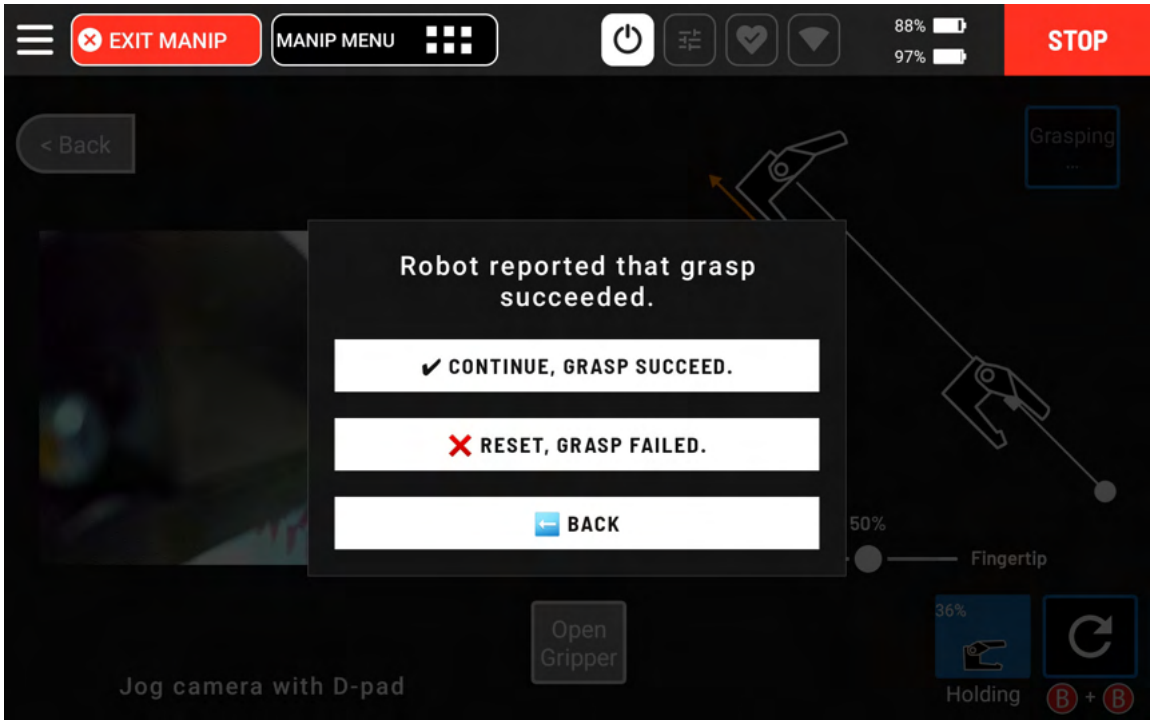


4. Adjust the **Grasp location** slider (A) to indicate what part of the gripper should contact the object, then slowly adjust the distance slider (B) to move the gripper closer to the target.



5. If the **Auto Grasp** button (C) appears, select it to semi-automatically complete the grasp. Otherwise, continue to adjust the distance slider and then select **Close Gripper** to attempt a grasp.

6. Verify that the object is firmly grasped as expected, either by direct visual inspection or by the use of remote cameras.



a. If the grasp appears successful, select **CONTINUE, GRASP SUCCEEDED** to continue manipulation with the grasped object.

b. If the grasp appears unsuccessful, select **RESET, GRASP FAILED** to stow the arm and continue manipulation without grasping, or select **BACK** to dismiss the message and try again.

> **WARNING**
> Continuing manipulation with a failed or unstable grasp may result in sudden and unpredictable movements of Spot and Spot Arm.

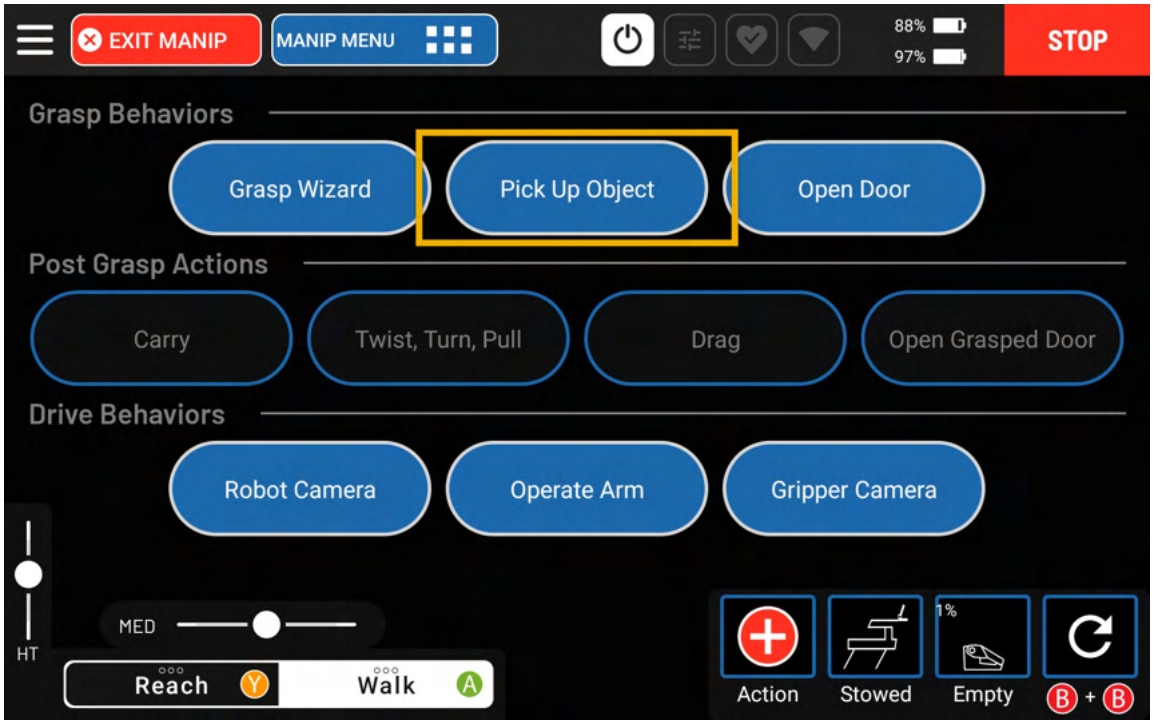
5.3.2. Pick Up Object

Use Pick Up Object to semi-automatically grasp an object so it can be moved in the environment.

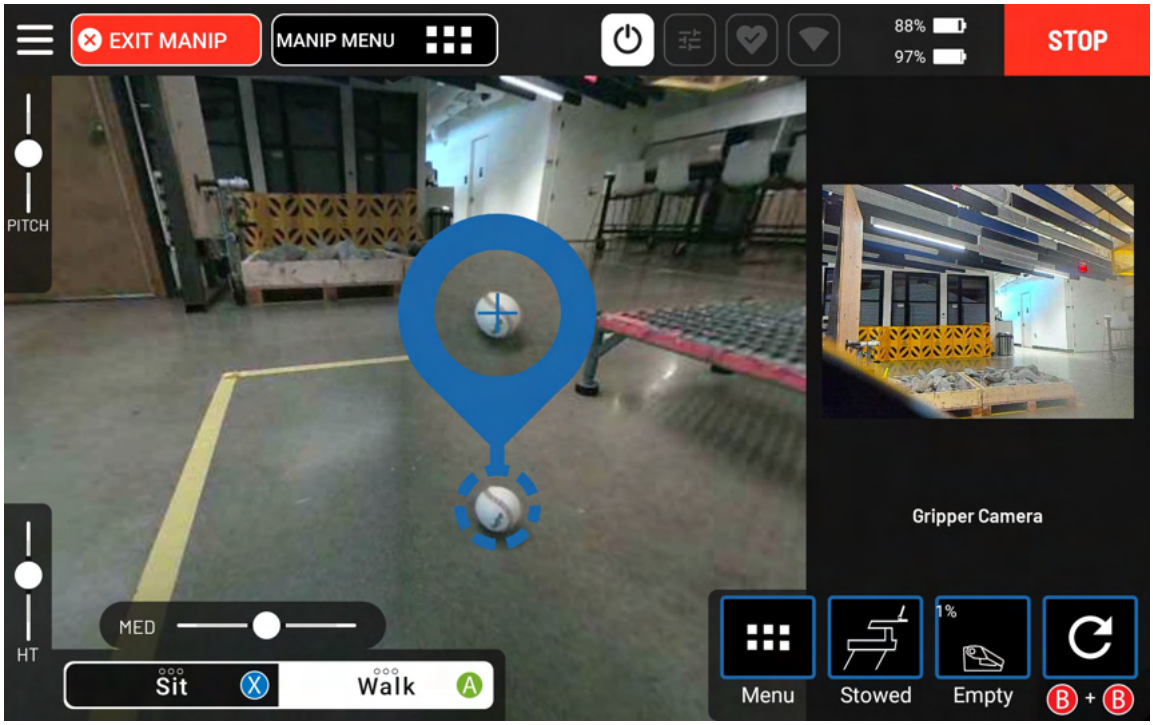
Pick Up Object is similar to the Grasp Wizard, but is optimized for grasping small, movable objects.

To semi-automatically grasp an object so it can be picked up:

1. On the tablet controller, open the Manipulation Menu and select **Pick Up Object**.



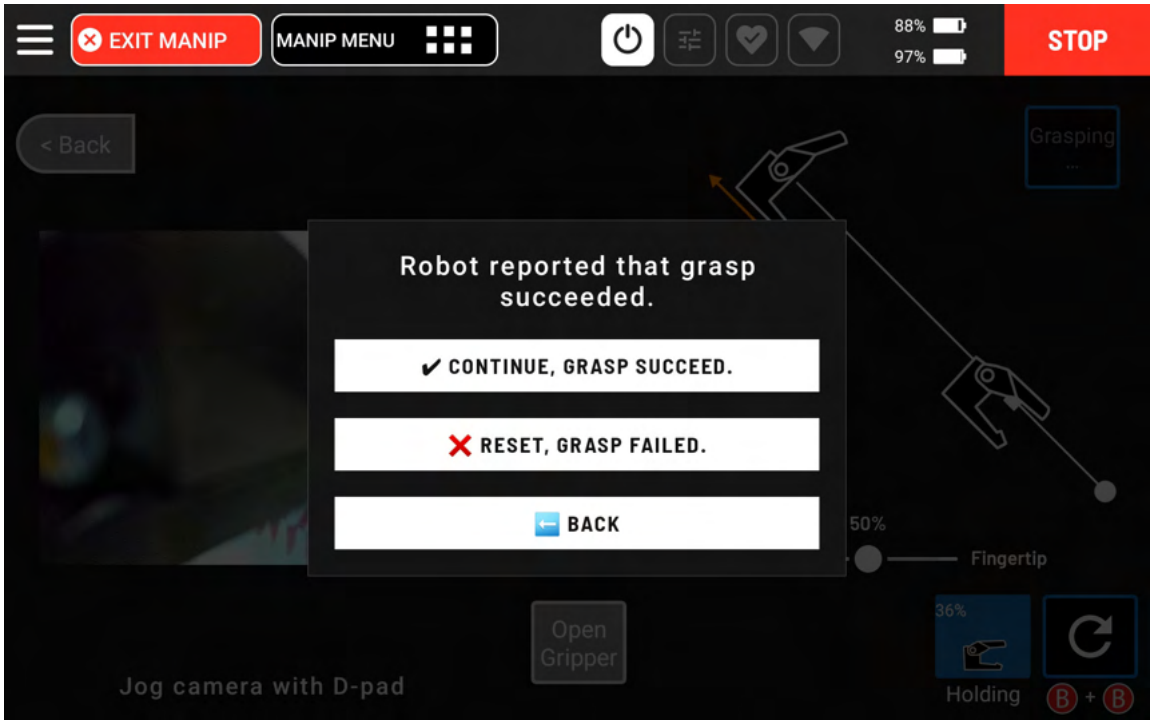
2. Touch on either camera view to select the object.



3. Adjust the **Grasp locationGrasp location** slider (1) to indicate what part of the gripper should contact the object, then select a grasp orientation (2).

4. Wait for Spot with Spot Arm to approach the object and attempt a grasp.

5. Verify that the object is firmly grasped as expected, either by direct visual inspection or by the use of remote cameras.



a. If the grasp appears successful, select **CONTINUE, GRASP SUCCEEDED** to continue manipulation with the grasped object.

b. If the grasp appears unsuccessful, select **RESET, GRASP FAILED** to stow the arm and continue manipulation without grasping, or select **BACK** to dismiss the message and try again.

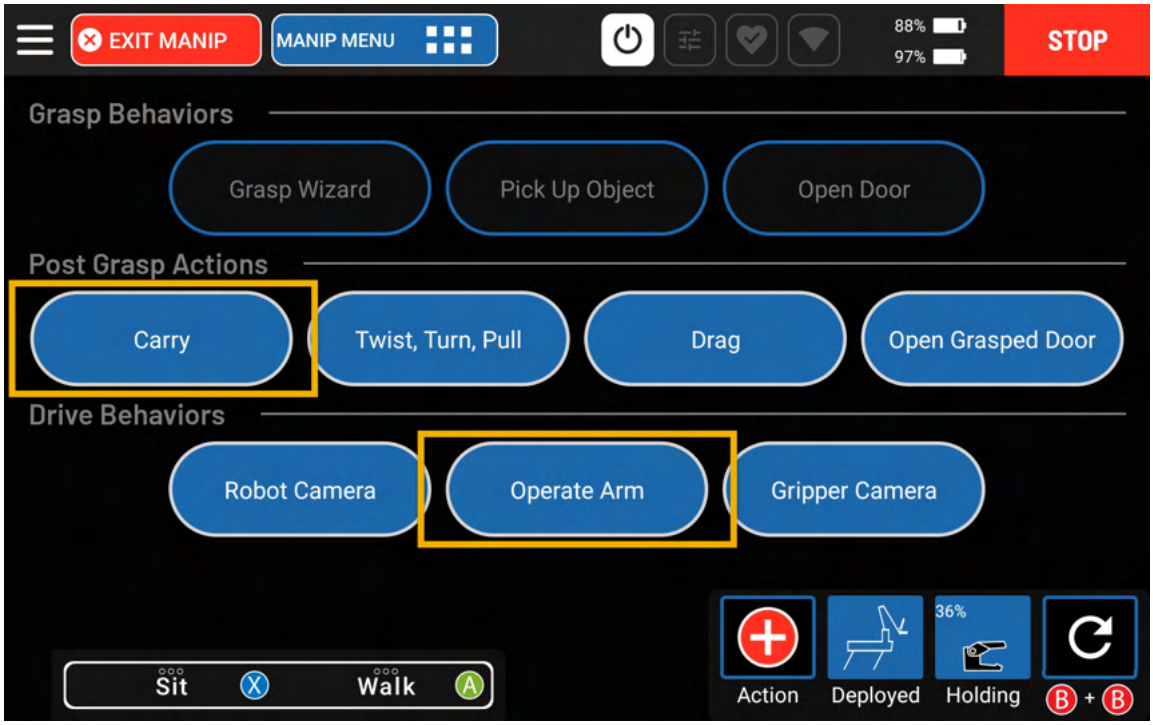
WARNING

Continuing manipulation with a failed or unstable grasp may result in sudden and unpredictable movements of Spot and Spot Arm.

NOTICE

If Spot with Spot Arm repeatedly fails to achieve a firm grasp using Pick Up Object, try the Grasp Wizard.

6. To lift the object, choose one of the following options from the Manipulation MenuManipulation Menu:



- Select **Carry** to lift the object and drive Spot (see Carrying and Dragging).
- Select **Operate Arm**, then use the arm controls to manually move and place the object in a nearby location (see Operate Arm).

5.4. Constrained Manipulation

Constrained manipulation involves objects that have limited axes and ranges of movement, such as switches, levers, cranks, valves, wheels, cabinets, and drawers. For example, a drawer is constrained to slide in or out on a single axis.

During constrained manipulation, Spot with Spot Arm can exert very high forces on the grasped object. Successful operation relies heavily on obtaining a good initial grasp that is aligned with the configuration shown in the Spot App.

WARNING

If a loss of grasp occurs during constrained manipulation, Spot and Spot Arm may move suddenly and unpredictably.

Spot's obstacle avoidance capability does not extend to Spot Arm.

Do not perform constrained manipulation on or around fragile or sensitive equipment.

Spot Arm supports the following semi-automatic constrained manipulation behaviors.

Behavior	Description
Turn Crank	Rotate a crank that has a handle that spins freely at the end of the crank shaft. If the crank handle is fixed to the crank shaft, use Turn Wheel instead.
Turn Wheel	Spin a wheel by grasping the rim, or rotate a crank that has a handle that is fixed to the end of the crank shaft.
Turn Ball Valve	Rotate a valve that is operated by a lever arm. For valves with no lever, use Turn Knob instead. This behavior is similar to Pull Lever, but is better suited for lever arms 30 cm or less in length.
Turn Knob	Rotate a knob, or rotate a ball valve that has no lever arm attached.
Open Drawer	Pull a drawer open or closed along a linear axis.
Open Cabinet	Swing a cabinet door open or closed around the hinges.
Pull Lever	Rotate a lever around a pivot point. This behavior is similar to Turn Ball Valve, but is better suited to lever arms more than 30 cm long.

CAUTION

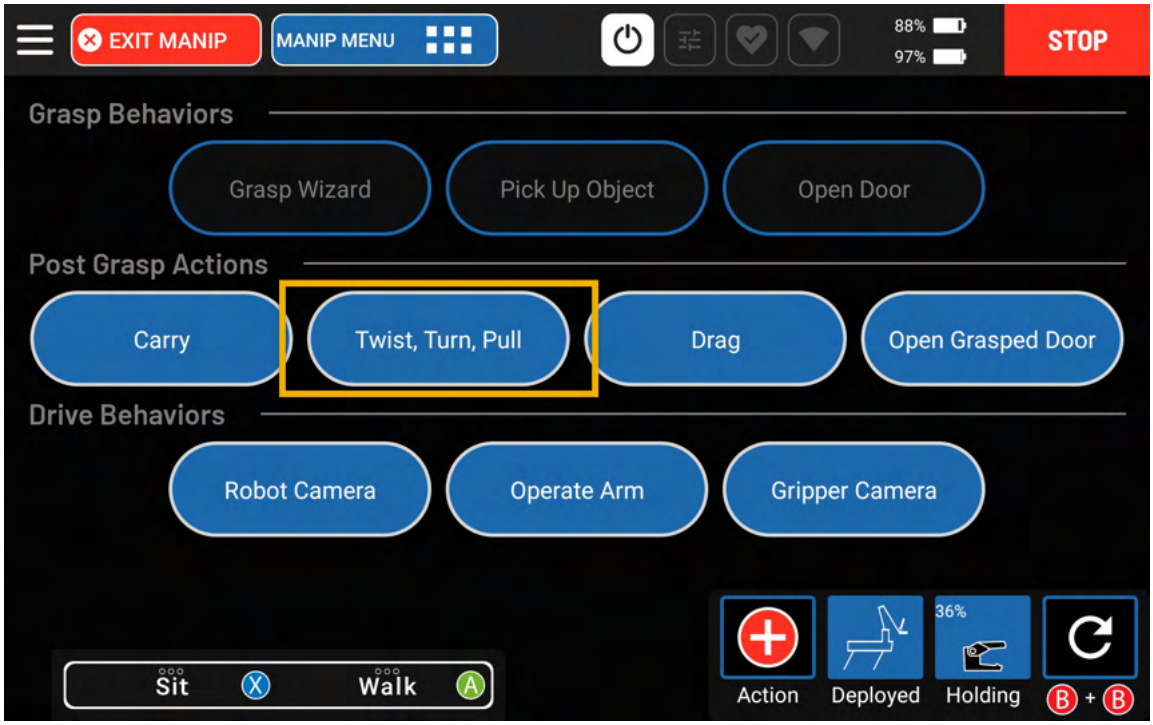
While it is possible to accomplish constrained manipulation operations via direct manual control of the manipulator and gripper, the preset behaviors offer a simplified set of force-limited controls and automate the coordination of Spot Arm's joints and the stability of Spot's body. Use the presets whenever possible.

5.4.1. Twist, Turn, Pull

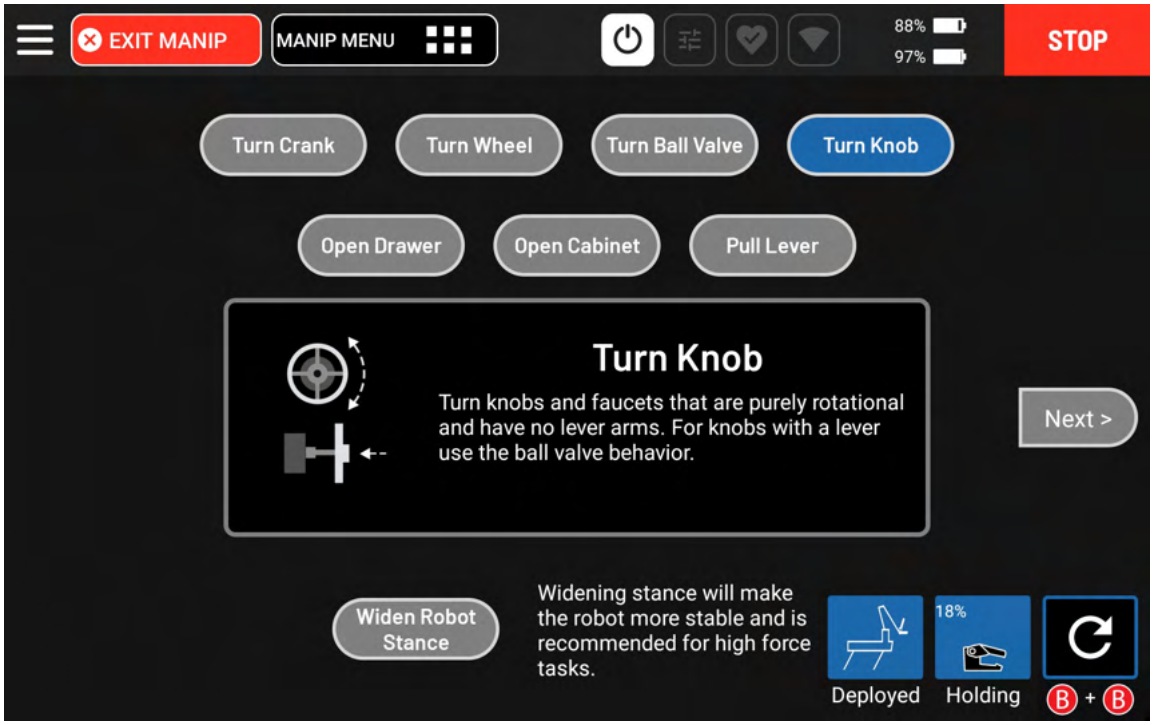
To use Spot Arm's preset constrained manipulation behaviors:

1. Execute a successful grasp using the **Grasp Wizard** (see Grasping), or by direct manual control.

2. Open the Manipulation Menu, then select **Twist, Turn, Pull**.



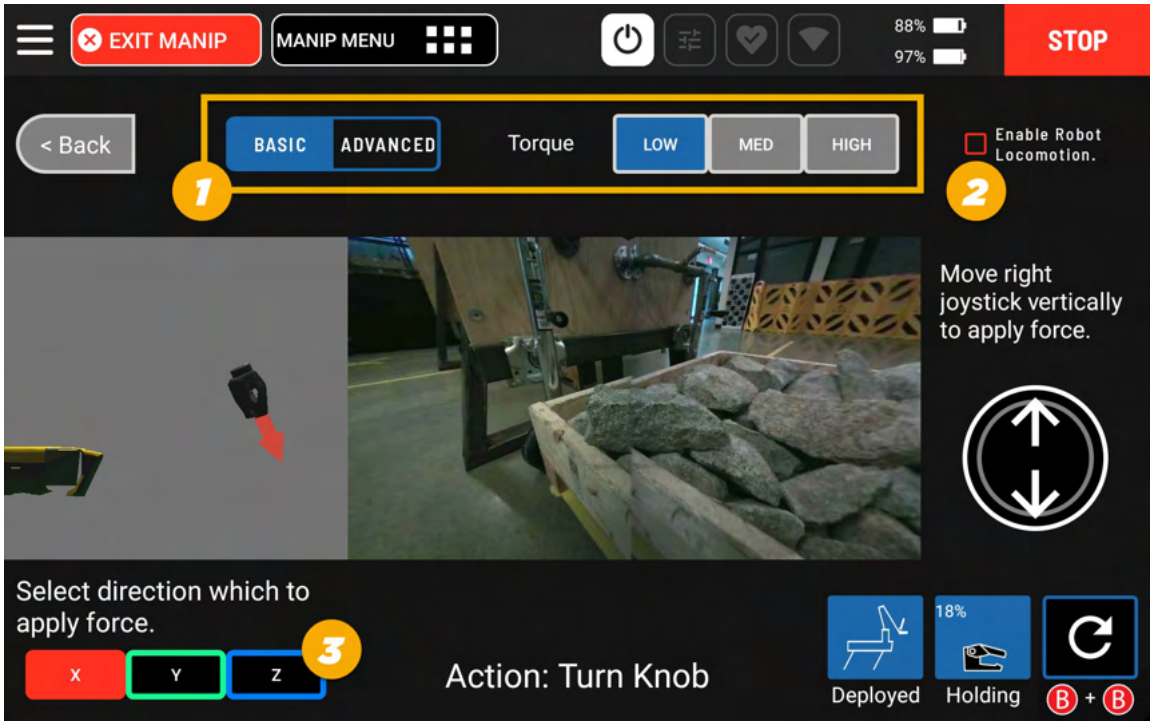
3. Select a constrained manipulation behavior, then select **Next**.



   a. For **Turn Crank**: Select a starting gripper position, making sure to match both the position and the orientation of the gripper (perpendicular or parallel to the plane of rotation), then select **Next**.

   b. For **Turn Ball Valve**: Select left-handed or right-handed configuration, then select **Next**.

4. Adjust the presets as needed.



No.	Setting	Description
1	**Torque**	**BASIC**: Select **LOW** (31.5 N), **MED** (63.0 N), or **HIGH** (80.0 N) to limit the maximum force applied. **ADVANCED**: Drag the slider to select the maximum amount of force applied, up to 118 N.
2	**Enable Robot Locomotion**	Allows Spot to move its body to better accomplish constrained manipulation tasks (e.g. stepping back to make room to open a drawer). Off by default. **NOTICE** Enabling robot locomotion during constrained manipulation can cause a reduction in overall force Spot Armcan apply. If Spot Armappears to be stuck or struggling, try disabling robot locomotion. If **Torque** (1) is set to **HIGH**, robot locomotion will be automatically disabled.
3	**Direction to apply force**	Apply initial force along the X, Y, or Z axis.

5. Tilt the right joystick along its Y axis to apply force.
6. To finish constrained manipulation, reset the arm or select another behavior from the Manipulation Menu.

5.5. Carrying and Dragging

Carrying and dragging involve moving an object in the environment with Spot Arm.

5.5.1. Carry

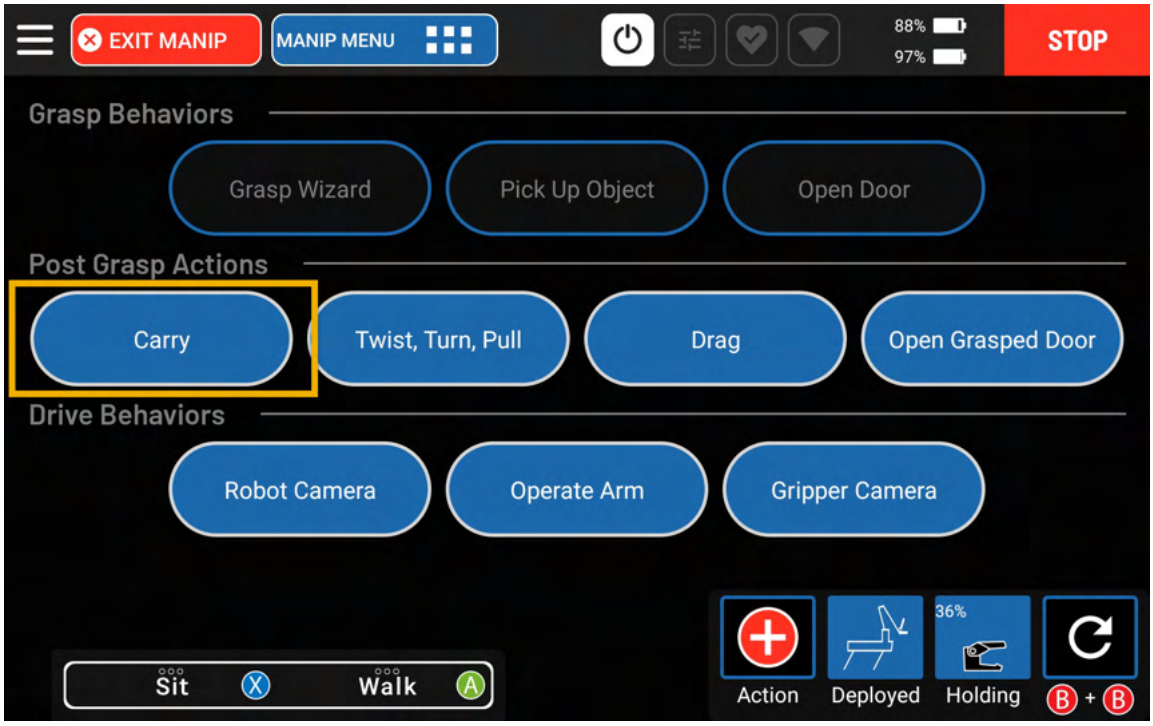
Use Carry to lift and hold an object while Spot moves around.

CAUTION

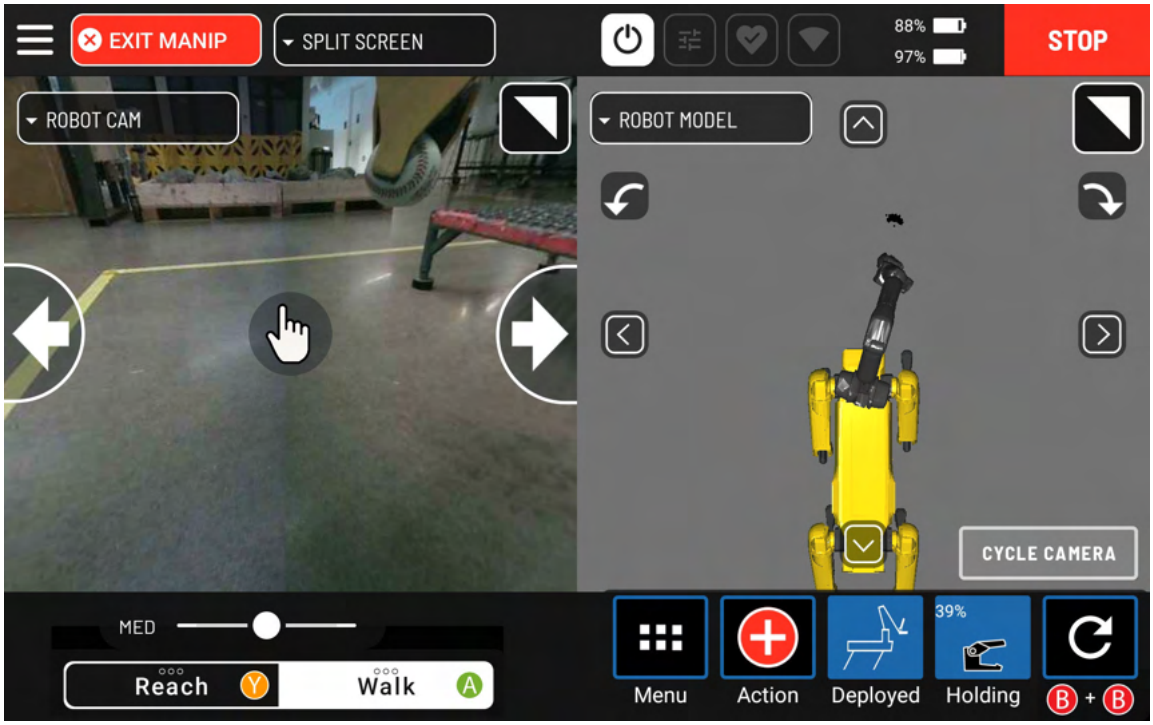
- Spot's obstacle avoidance capability does not extend to Spot Arm or carried objects.
- Carrying objects greater than 5 kg, or carrying objects with Spot Arm in a horizontally extended configuration, will increase the likelihood of Spot becoming unbalanced.

To carry an object with Spot Arm:

1. Execute a successful grasp using **Pick Up Object** or the **Grasp Wizard** (see Grasping), or by direct manual control.
2. From the Manipulation Menu, select **Carry**. The arm will move to the Carry position.



3. Drive Spot, then use the arm controls to manually place the object.



WARNING

While moving with the manipulator deployed forward, collisions with people and objects or fixtures can occur. Small rotations of the base will determine large rotations of the manipulator.

NOTICE

By default, Spot with Spot Arm assumes whatever object it is holding is not stowable. Stowing or resetting the arm will attempt to release the grasp.

You can set a held item as stowable in the manipulator controls menu (see Operate Arm.

5.5.2. Drag

Use Drag to pull an object from one location to another. During dragging, the manipulator acts like a tow cable while Spot moves in a rearward direction (including turns). Drag cannot be used to push an object, only to pull.

During dragging, Spot with Spot Arm can exert very high forces on the grasped object. Successful operation relies heavily on obtaining a good initial grasp.

CAUTION

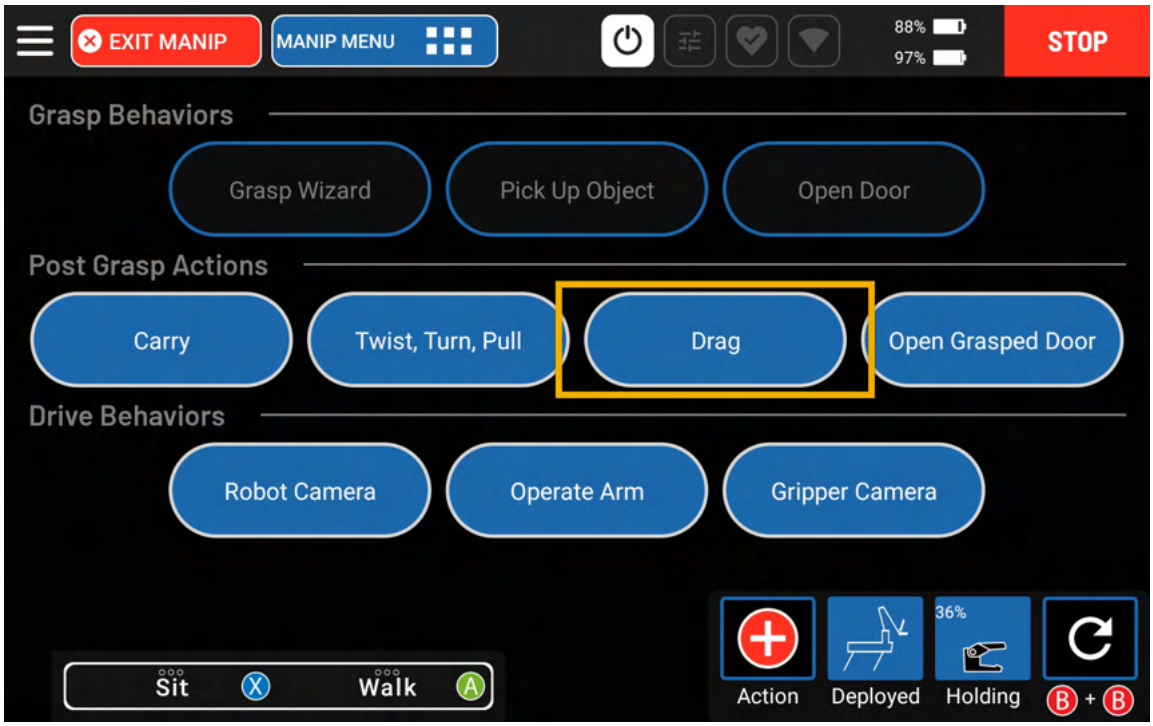
If a loss of grasp is detected while dragging, Spot Arm will freeze but Spot will continue to respond to movement commands.

Spot's obstacle avoidance capability does not extend to Spot Arm.

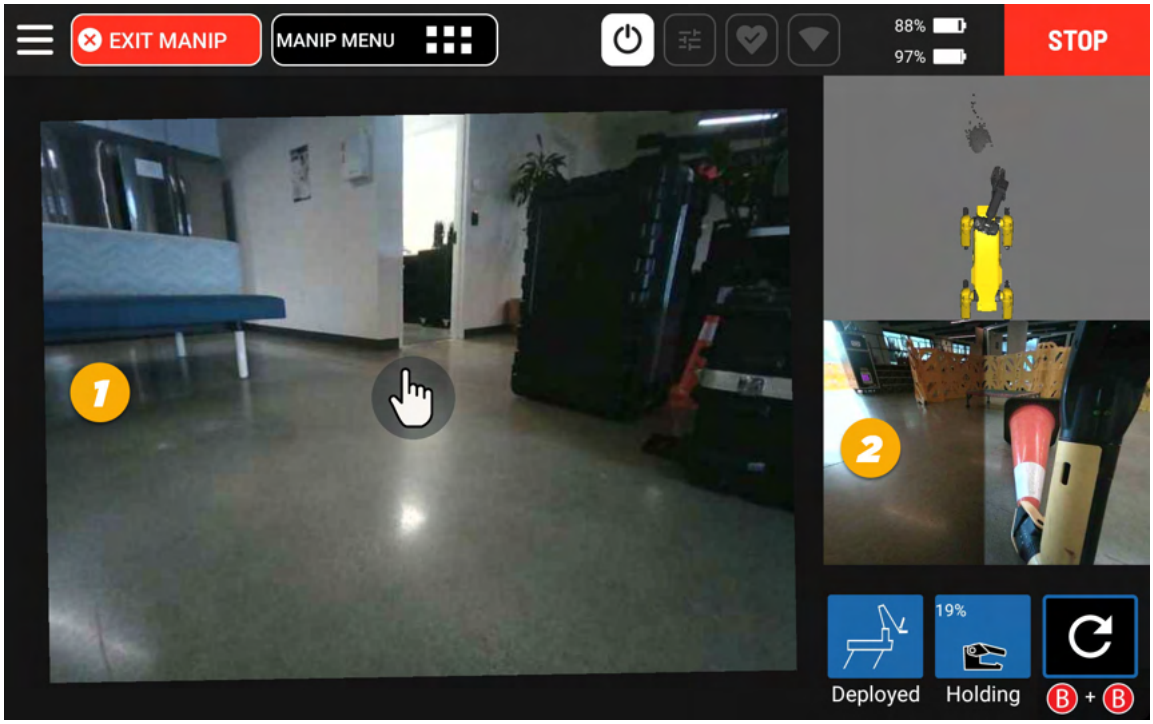
Do not drag fragile or sensitive equipment.

To drag an object with the Spot Arm:

1. Execute a successful grasp using the **Grasp Wizard** (see Grasping), or by direct manual control.
2. Open the Manipulation Menu, then select **Drag**.



3. Drive Spot backwards to drag the object. The main camera view (1) shows Spot's rear body camera, while the inset (2) shows the front body camera.



4. To finish dragging, reset the arm or select another behavior from the Manipulation Menu.

5.6. Opening Doors

Spot with Spot Arm can open many of the doors found in typical industrial facilities and other buildings. There are several ways to perform this behavior.

Method	Description	Manual operation	Autowalk
Semi-automatic	You set the location and type of the door handle, the position of the hinge, and the swing direction. Spot then approaches the door, grasps the handle, opens the door, and walks through.	✓	✓
Manual grasp	You execute a successful grasp of the door handle, then set the position of the hinge and the swing direction. Spot then opens the door and walks through.	✓	×

WARNING

Spot cannot detect people or obstacles on the other side of a closed door. Unexpected hazards may occur during or after door opening.

Doorways are constrained spaces where Spot's obstacle avoidance system may not be able to prevent collisions with nearby people or objects.

- Verify the presence of hazards when operating Spot remotely to open doors.
- Do not attempt to open a door that Spot is already opening.
- Do not stand in or near a doorway that Spot is traversing, or attempt to pass Spot through a doorway.
- Always stay 3 meters away from Spot and Spot Arm during operation.

CAUTION

If Spot experiences a navigation error, fall, or other failure during door opening, it may become an obstacle that interferes with the normal operation and use of the door. Before using Spot to open doors in Autowalk missions or remote operation, assess the operating environment for risks posed by a robot laying on the ground, including:

- Doors unexpectedly propped open.
- Doors unexpectedly blocked closed.
- Restricted passage through doorways.

NOTICE

Moving object detection is disabled while Spot with Spot Arm is opening and walking through a door.

For details, refer to documentation in the Boston Dynamics Support Center (see Appendix A: Supplemental Information).

NOTICE

Spot and Spot Arm may cause cosmetic damage to doors during door opening, especially with repeated use.

5.6.1. Door Compatibility and Limitations

Before using Spot to open a door, inspect the door and its surroundings for damage, hazards, and compatibility with the following parameters. If conditions that would prevent safe and successful door opening cannot be remedied, do not use Spot to open the door.

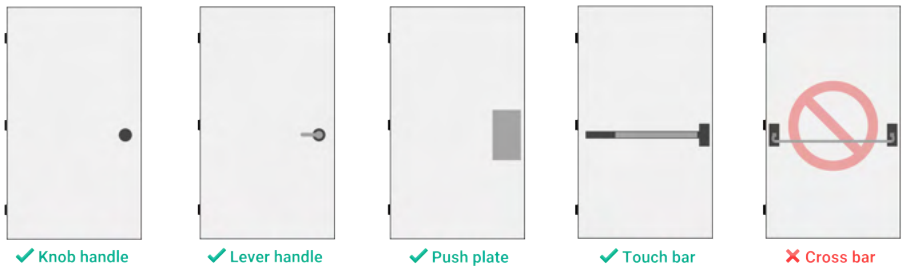
If a door included in an Autowalk mission must later be replaced or modified, check the new door for compatibility with these specifications and with the recorded door-opening behavior. Missions may need to be edited or re-recorded to accommodate changes to doors.

CAUTION

Opening damaged or malfunctioning doors may cause unexpected hazards. Do not use Spot to open a door that appears to be damaged or malfunctioning.

5.6.1.1. Compatible Doors

Spot with Spot Arm can open doors that meet the following criteria:

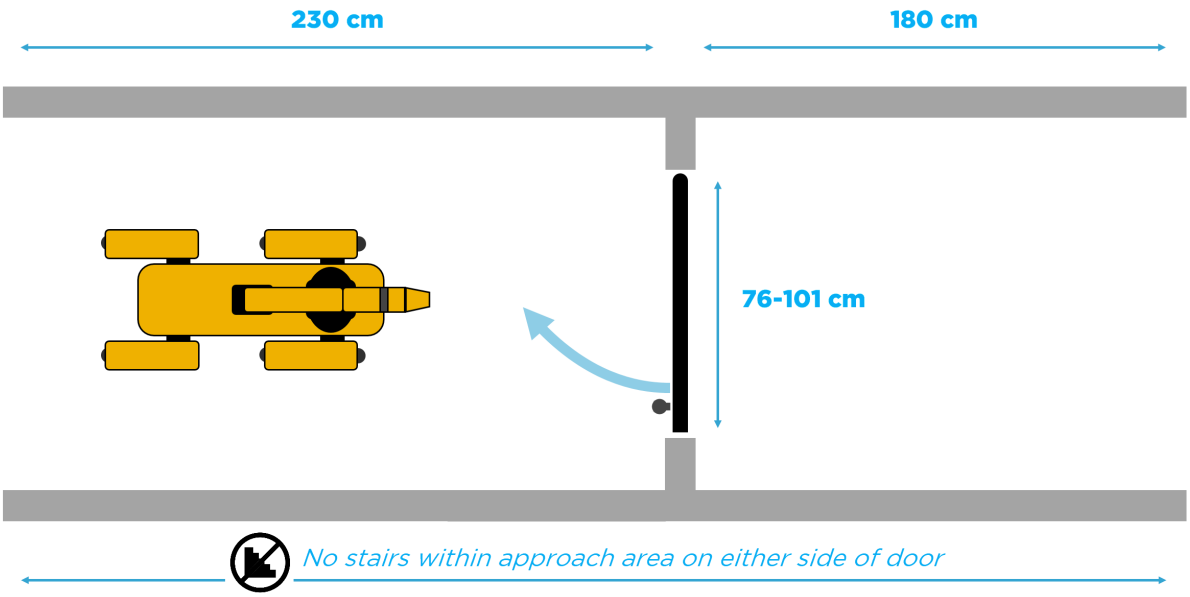
Door attribute	Requirements
Force required to open	< 70 N to push or pull open from closed < 40 N to hold open between 45 and 90 degrees **NOTICE** Instructions on measuring the force required to open a door are available in the Boston Dynamics Support Center (see Appendix A: Supplemental Information).
Supported mechanisms	Rotating handles: Knobs, levers Flat push surfaces: Push plates, touch bars  **NOTICE** Doors with fixed (non-rotating) handles must be opened using the Open Grasped Door method described later in this document. Cross bars (thin bars that pivot toward the door surface) are not supported.
Door width	Min: 76 cm Max: 101 cm

5.6.1.2. Approach Area Layout

Spot requires sufficient space on both sides of the door to complete the full door-opening behavior. Spot must be able to approach the door head-on.

Minimum space required:

- 230 cm on pull side
- 180 cm on push side
- No stairs within approach area on either side of door



Nominal dimensions for opening doors with Spot and Spot Arm.

WARNING

Spot may fall if it encounters a staircase during door opening. Spot cannot navigate stairs while opening a door.

Do not use Spot to open a door if there are stairs within the approach area on either side of the door.

5.6.1.3. Limitations of Door Opening

Door attribute	Limitation	Remedy
Direction of travel	Doors that can only be opened in one direction are not supported in Autowalk. This includes double doors where each half allows travel in only one direction. **CAUTION** Replaying a mission that includes a one-way door may result in hazards due to unpredictable behavior of Spot Arm, or navigation failures.	Modify the door to allow it to be opened in both directions.
Door material	The gripper depth sensor is unable to detect transparent materials such as glass or clear plastic, and will not be able to identify transparent doors.	Remove or replace the door.
Door color	The gripper depth sensor is unable to detect IR-absorbent materials, and may not be able to identify black or dark-colored doors.	Cover a 30 cm x 30 cm section of the door surface around the handle with a more reflective material, such as colored tape or a piece of paper.
Handle color	The gripper depth sensor is unable to detect IR-absorbent materials, and may not be able to identify black or dark-colored door handles.	Cover the door handle with a more reflective material, such as colored tape.
Slippery handle	The gripper may slip on knobs or handles made of low-friction materials or coated in slippery substances such as grease or oil.	Clean door handles regularly. If problems persist after cleaning, cover the handle with a less slippery material.

Door attribute	Limitation	Remedy
Gripper orientation	When manually executing a grasp on a door handle, certain gripper orientations may cause the arm to get stuck in a position where it cannot complete the door opening.	Pay careful attention to gripper orientation when manually executing a grasp on a door handle. • Horizontal door handles must be grasped with the lower jaw of the gripper closer to the floor. • Round knobs are best grasped with the lower jaw of the gripper closer to the floor. • Fixed vertical handles can be grasped in any orientation.
Spring closure	Spot will not close unsprung doors after opening them.	Add a spring or other closure mechanism to the door.
Mount height	Doors should be mounted at ground or floor level. Spot uses its front leg to block the door during the opening process, and may not be able to block a raised door.	Rehang the door at ground level or add a raised platform at least the size of the approach area in front of the door.
Doors that must be opened simultaneously	Spot cannot open doors multiple doors at once, such as: • Secondary doors hung in the same frame as another door (storm doors, screen doors, security doors, etc.) • Double doors where both panels must be opened for Spot to pass through. • Any door that must be opened while Spot is already holding open another door.	Remove or replace the door.

WARNING

Spot cannot detect people or obstacles on the other side of a closed door. Unexpected hazards may occur during or after door opening.

Spot cannot detect transparent materials such as glass or clear plastic and may collide with transparent doors, resulting in shattered glass or unexpected behavior.

Unsprung doors may rebound off walls or objects. Rebound collisions may cause Spot to fall or compromise its stability.

- Verify the presence of hazards when operating Spot remotely to open doors.
- Do not use Spot to open doors made of transparent materials, such as glass or clear plastic.
- Do not operate Spot in direct proximity to unsprung doors.

5.6.2. Open Doors During Manual Operation

During manual operation you can command Spot with Spot Arm to open doors in two ways:

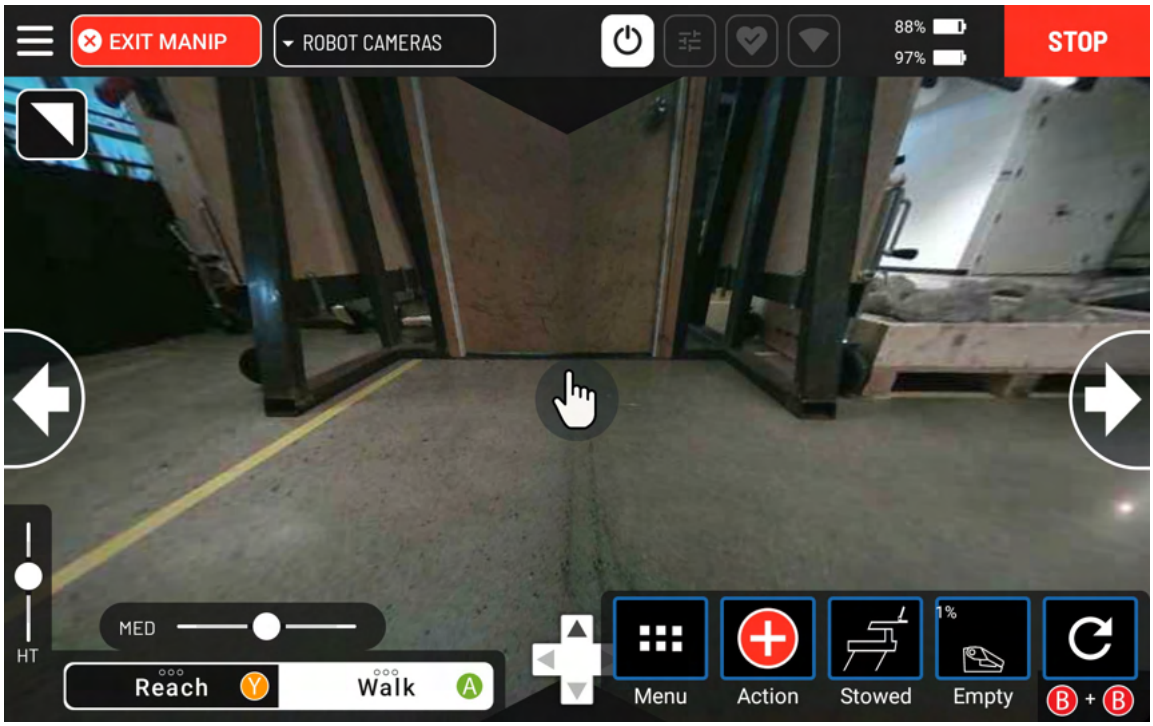
- **Semi-automatic (Open Door)**
  You set the location and type of the door handle, the position of the hinge, and the swing direction. Spot then approaches the door, grasps the handle, opens the door, and walks through.
- **Manual grasp (Open Grasped Door)**
  You execute a successful grasp of the door handle, then set the position of the hinge and the swing direction. Spot then opens the door and walks through.

5.6.2.1. Open Door

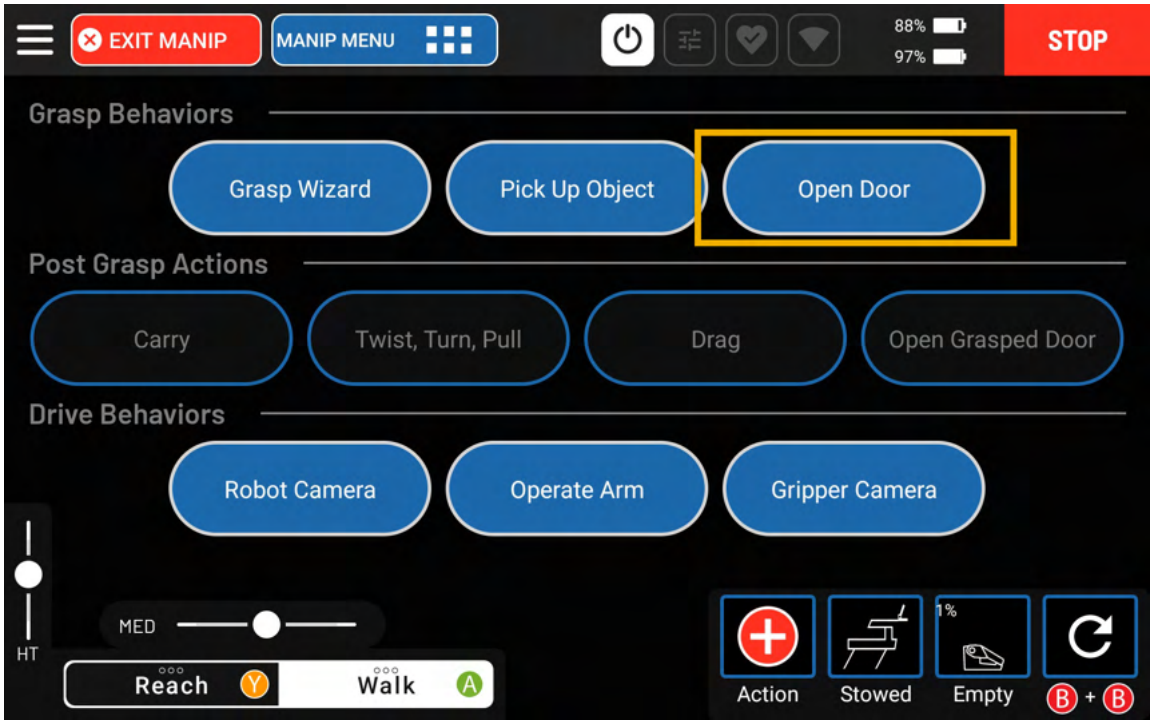
Use Open Door to have Spot semi-automatically approach and open a door.

To semi-automatically approach and open a door:

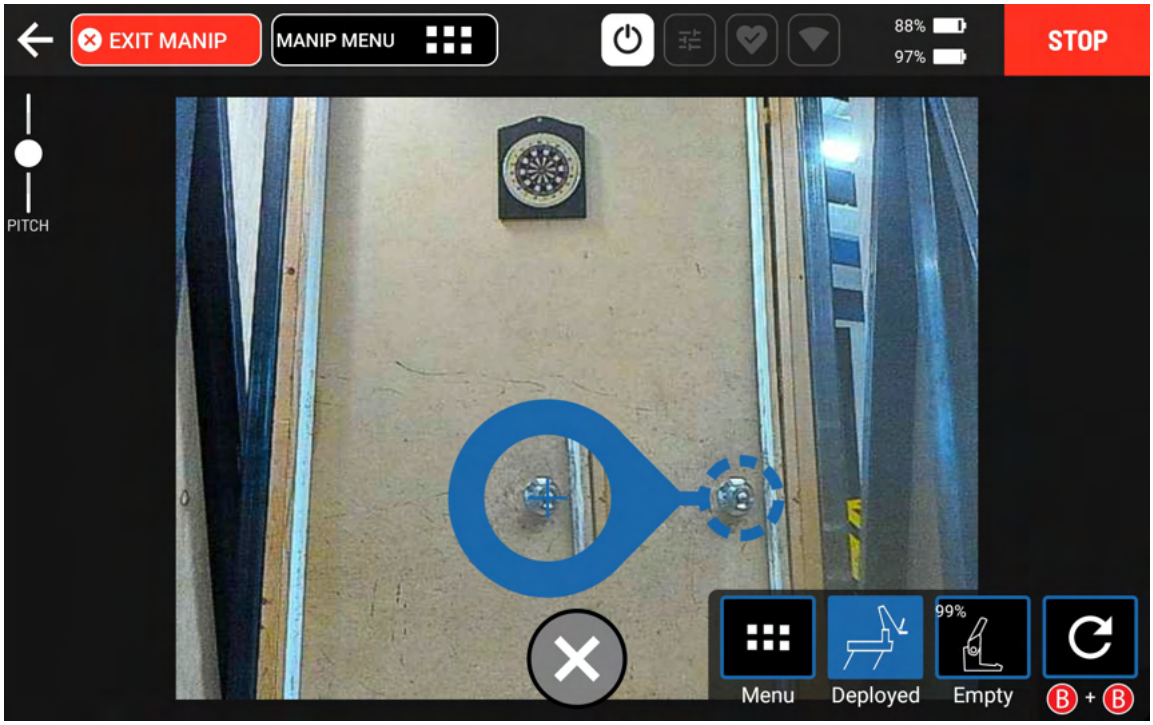
1. Drive Spot within 1.5 meters of the door. Spot should face the door straight on, in line with the middle of the doorway.



2. Open the Manipulation Menu and select **Open Door**.



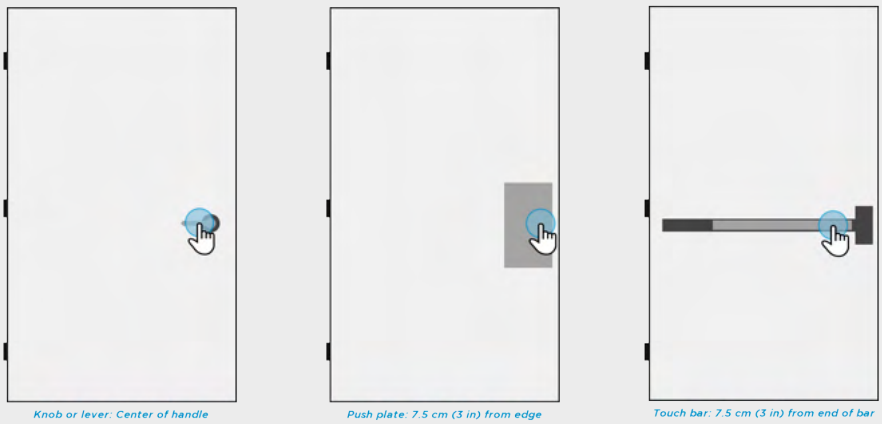
3. When prompted, select the door handle or push point.



NOTICE

When selecting door handles or push points:

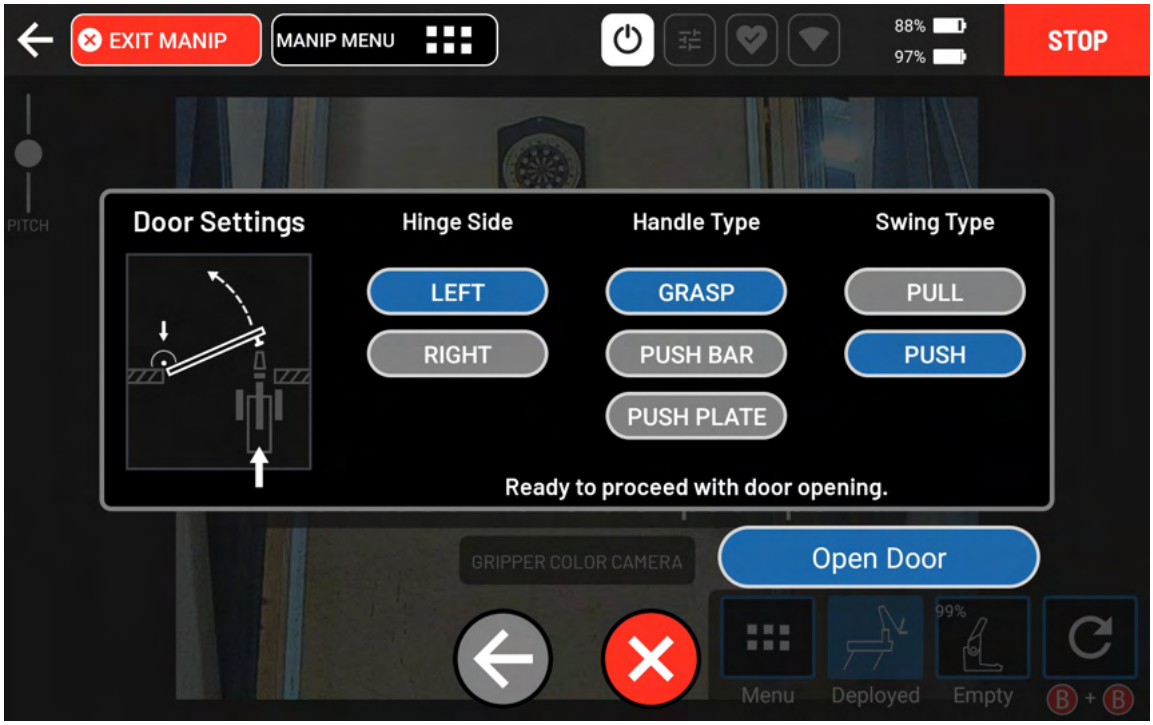
- For knob or lever handles, select the center of the handle.
- For push plates, select a location about 7.5 cm from the latch-side edge of the door.
- For touch bars, select a location about 7.5 cm from the latch-side end of the touch bar.



Handle and push point locations.

Doors with fixed (non-rotating) handles must be opened using the Open Grasped Door method described later in this document.

4. Choose the appropriate door settings, then select **Open Door**.



- **Hinge Side**: Select the location of the hinge as it appears to Spot.
- **Handle Type**: Select **GRASP** for knobs and levers.
- **Swing Type**: Select the type of motion Spot should use to open the door.

5. Wait until Spot has fully moved through the doorway and the success message appears.

5.6.2.2. Open Grasped Door

Use Open Grasped Door when Spot is already grasping a door handle.

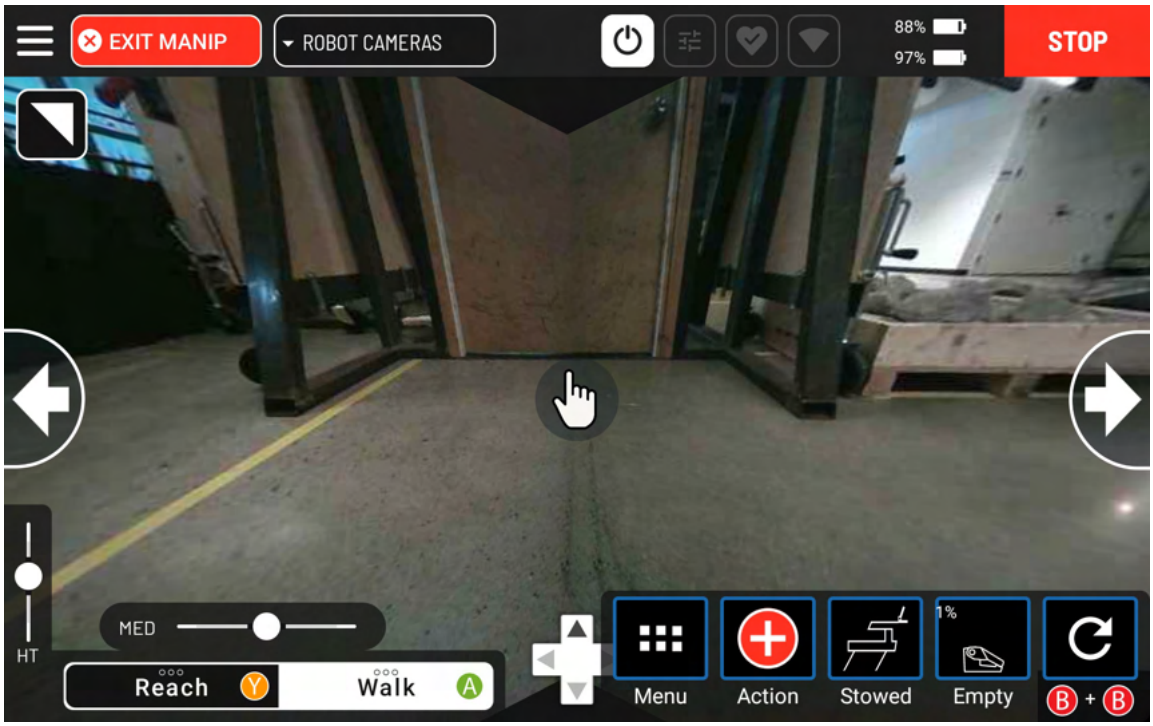
NOTICE

Open Grasped Door requires you to first execute a successful grasp of the door handle, either manually or with the Grasp Wizard (see Grasping).

Successful operation relies heavily on obtaining a good initial grasp. Use this method only if Spot is unable to open a door using the Open Door method described previously in this document.

To manually grasp a door handle, then have Spot semi-automatically open the door:

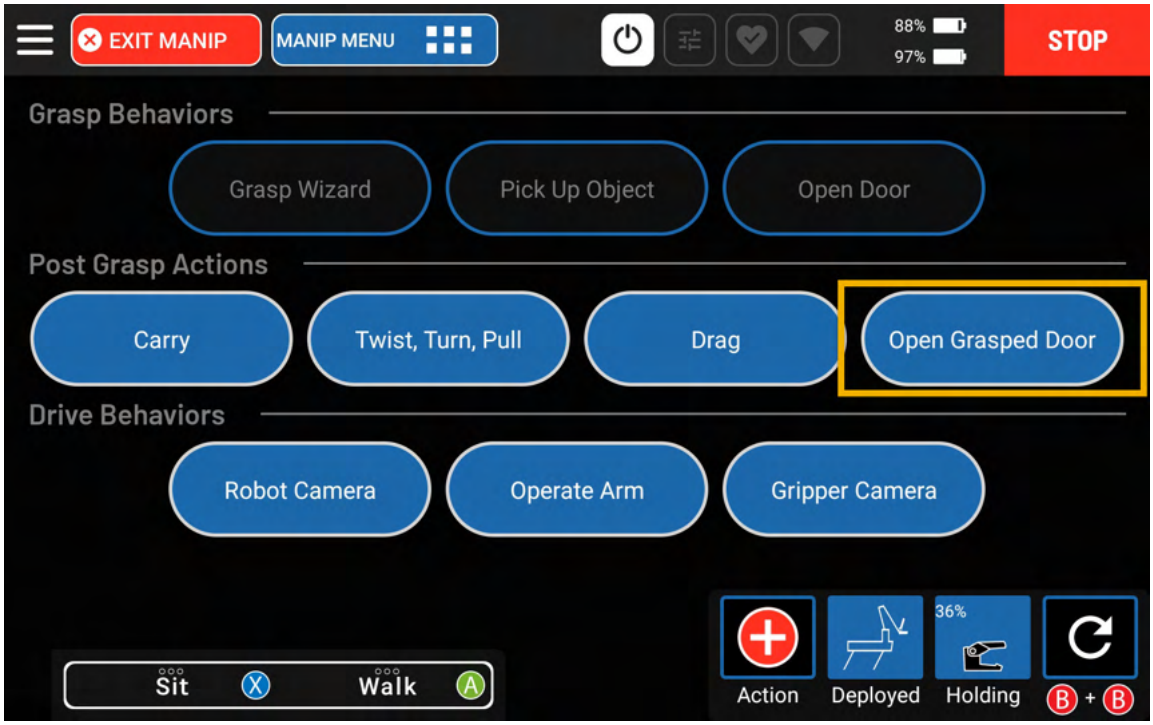
1. Drive Spot within 1.5 meters of the door. Spot should face the door straight on, in line with the middle of the doorway.



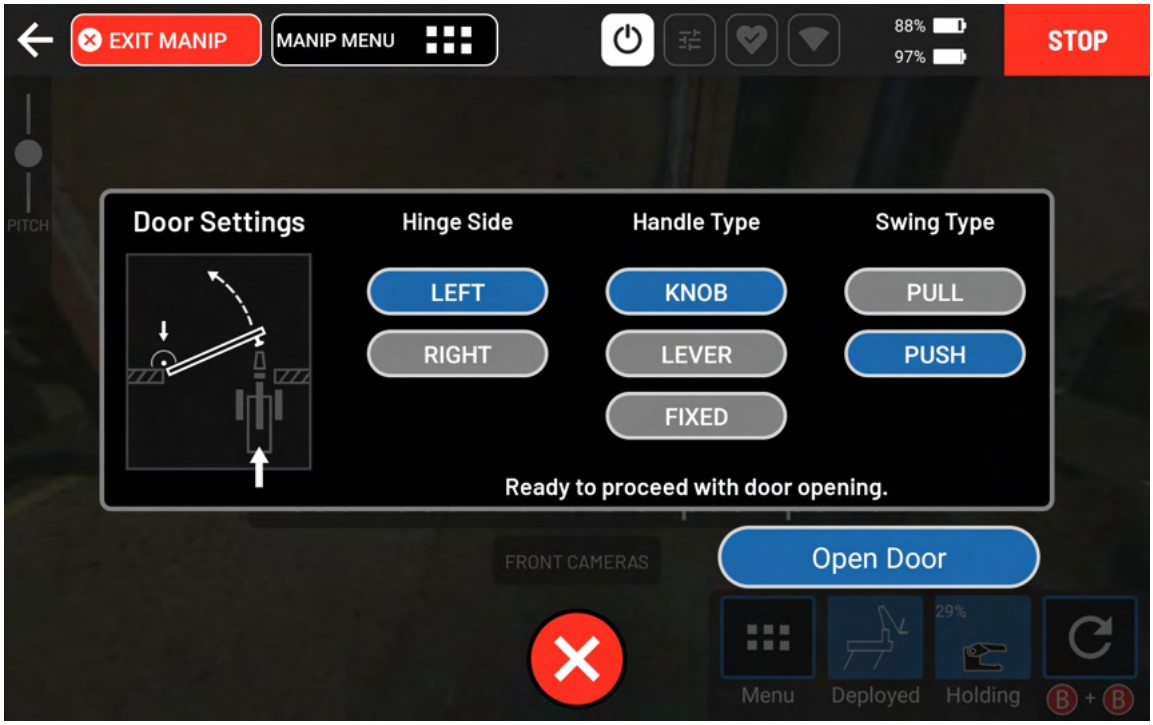
2. Execute a successful grasp using the Grasp Wizard (see Grasping), or by direct manual control.

> **NOTICE**
>
> - Horizontal door handles must be grasped with the lower jaw of the gripper closer to the floor.
> - Round knobs are best grasped with the lower jaw of the gripper closer to the floor.
> - Fixed vertical handles can be grasped in any orientation.

3. Open the Manipulation Menu and select **Open Grasped Door**.



4. Choose the appropriate door settings, then select **Open Door**.



- **Hinge Side**: Select the location of the hinge as it appears to Spot.
- **Handle Type**: Select the type of door handle. **FIXED** includes non-rotating knobs and levers as well as other non-rotating handle shapes.
- **Swing Type**: Select the type of motion Spot should use to open the door.

5. Wait until Spot has fully moved through the doorway and the success message appears.
Wait until Spot has fully moved through the doorway and the success message appears.

5.6.3. Open Doors in Autowalk

Spot with Spot Arm can open doors automatically during Autowalk missions if the door is included in the mission map.

During recording, you provide door parameters for both sides of the door. During replay, Spot follows the mission path and can dynamically reroute through the door in either direction if needed.

5.6.3.1. Record a Door-Opening Action

NOTICE

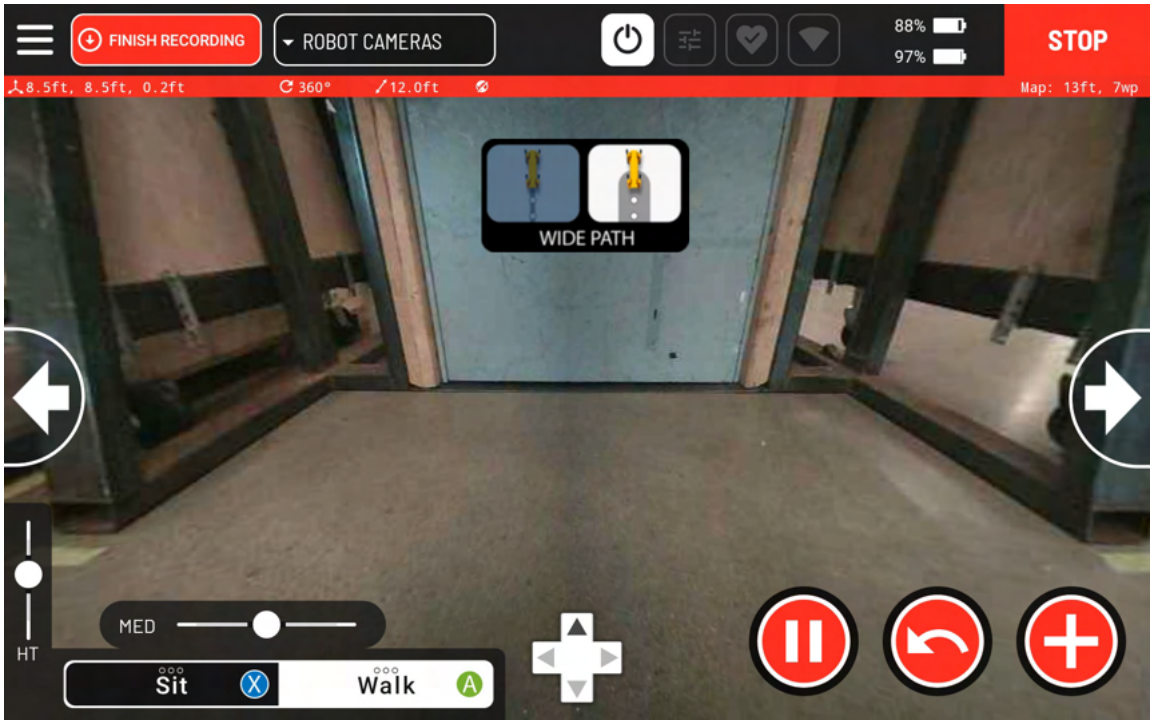
Before recording a mission that includes doors, verify that:

- Spot can open and traverse each door in both directions. Note that many push plate doors have fixed handles on the reverse side, which are not compatible with Autowalk.
- All doors will remain unlocked in both directions during the times when Spot will replay the mission.
- All doors are closed before recording begins.

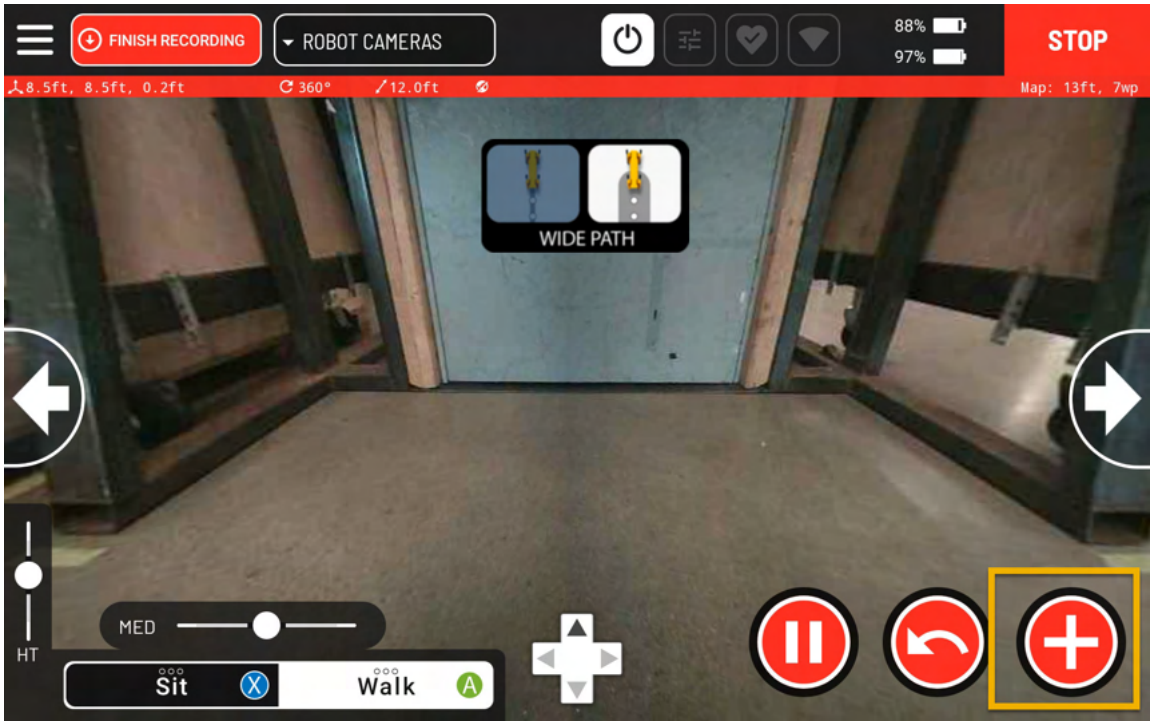
To add a door-opening action to an Autowalk mission:

1. Begin recording an Autowalk mission (see). For instructions, refer to documentation in the Boston Dynamics Support Center (see Appendix A: Supplemental Information).

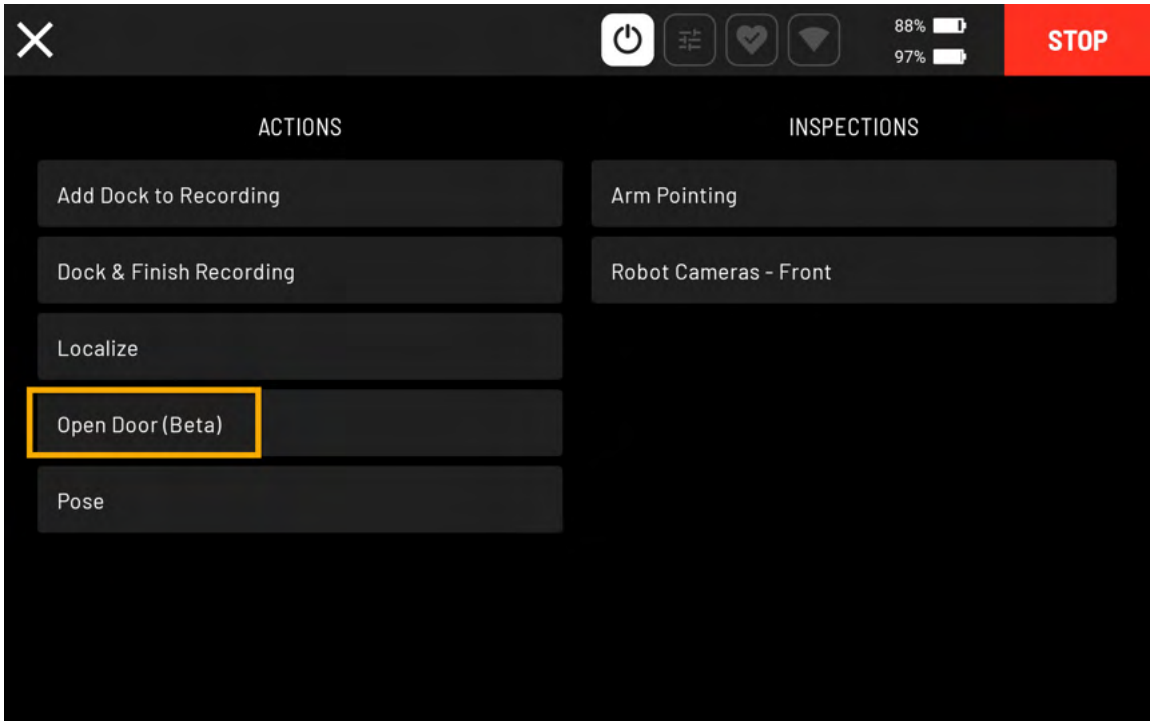
2. Drive Spot within 1.5 meters of the door. Spot should face the door straight on, in line with the middle of the doorway.



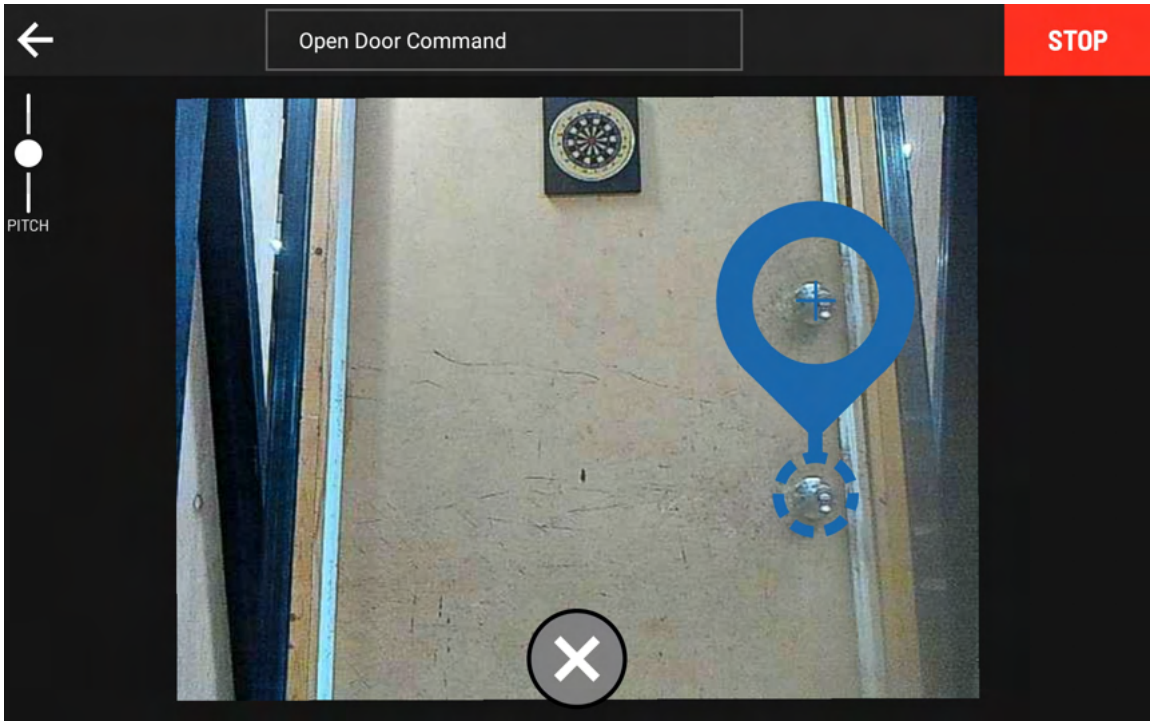
3. Select **Add Action**.



4. On the **ACTIONS** tab, select **Open Door**.



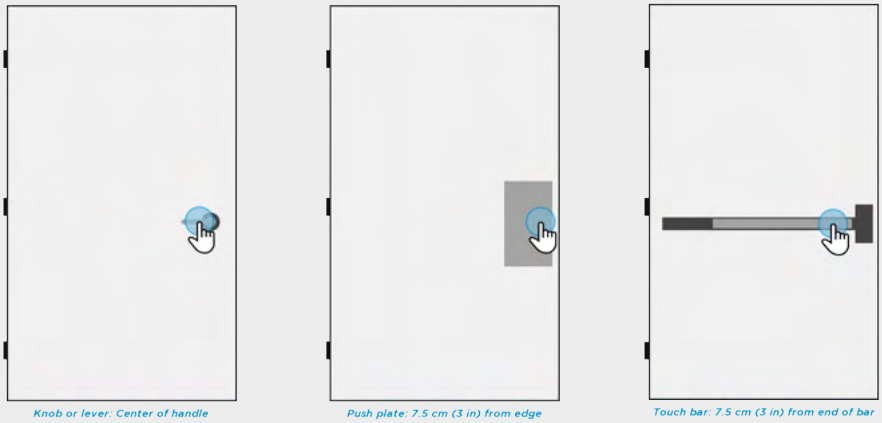
5. When prompted, select the door handle or push point.



NOTICE

When selecting door handles or push points:

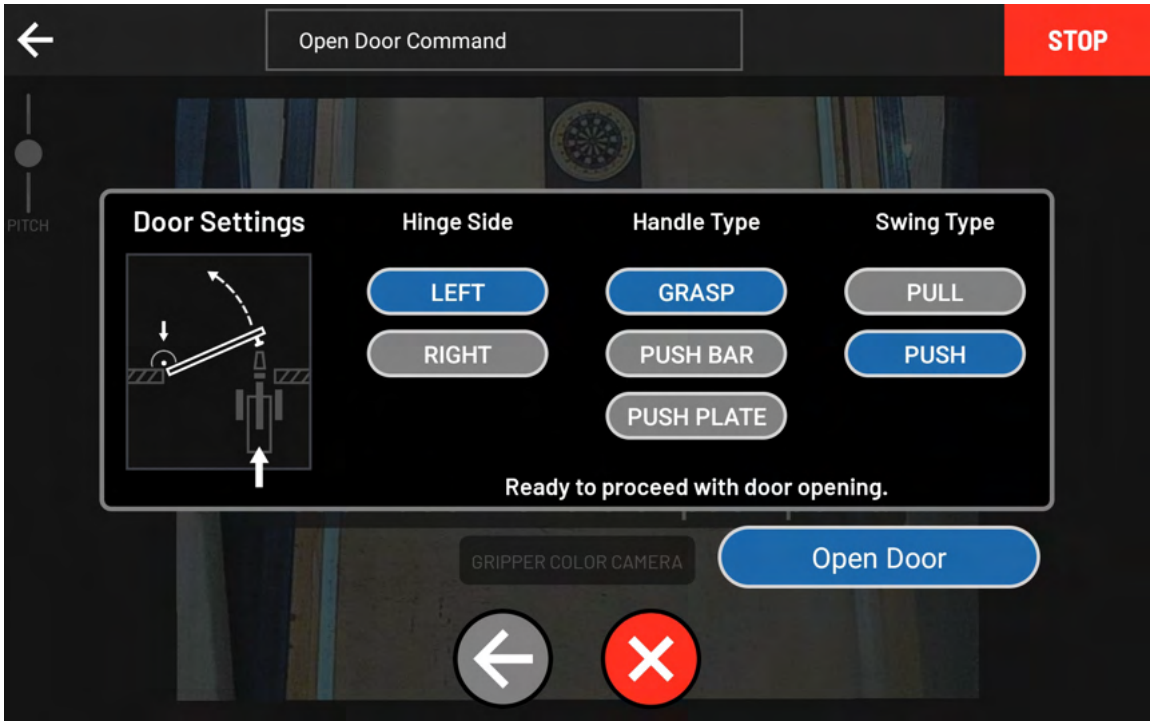
- For knob or lever handles, select the center of the handle.
- For push plates, select a location about 7.5 cm from the latch-side edge of the door.
- For touch bars, select a location about 7.5 cm from the latch-side end of the touch bar.



Handle and push point locations.

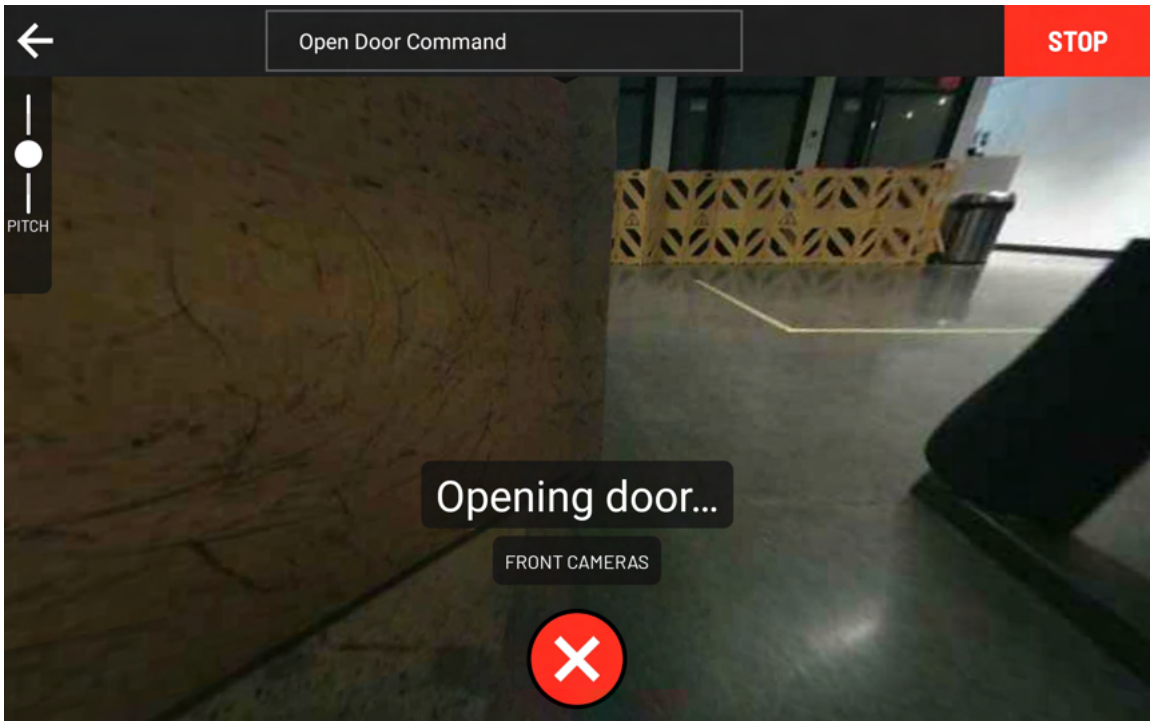
Doors with fixed (non-rotating) handles cannot be opened in Autowalk.

6. Choose the appropriate door settings, then select **Open Door**.

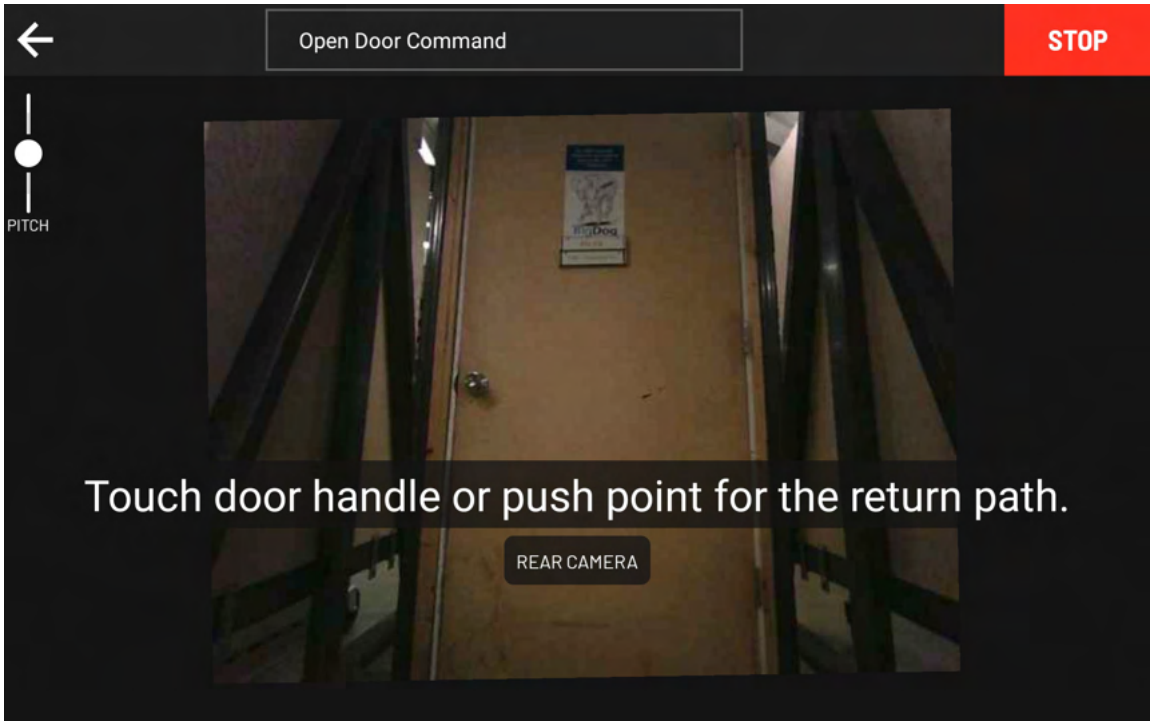


- **Hinge Side**: Select the location of the hinge as it appears to Spot.
- **Handle Type**: Select **GRASP** for knobs and levers.
- **Swing Type**: Select the type of motion Spot should use to open the door.

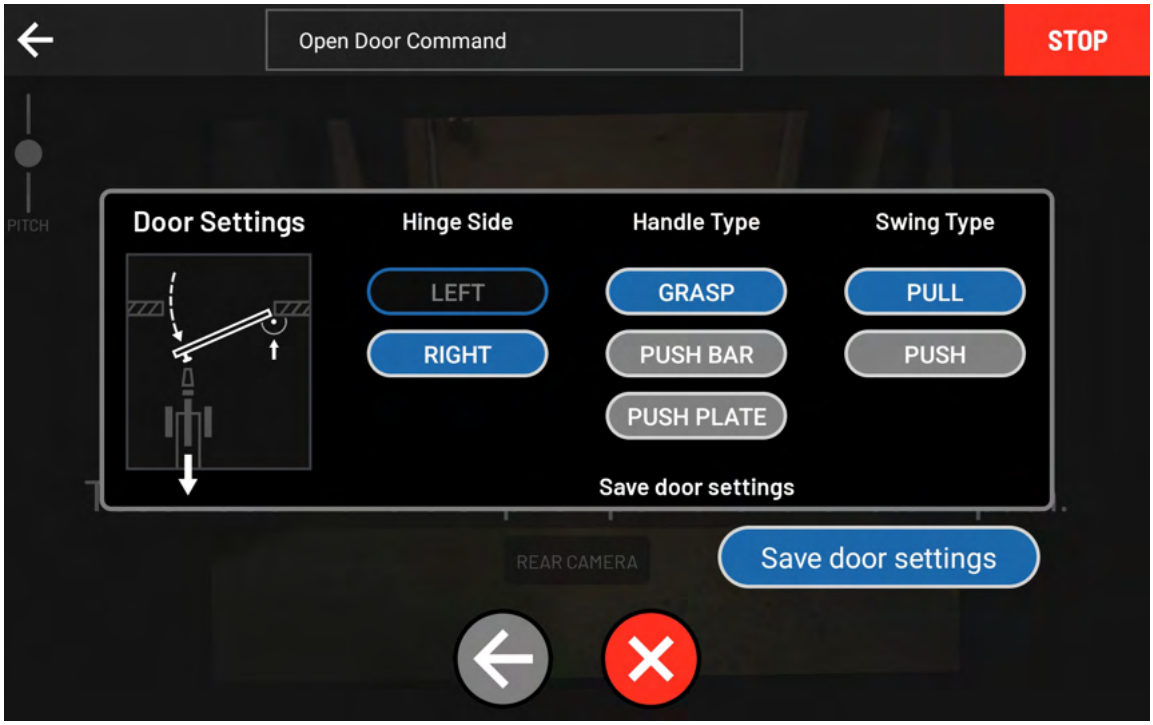
7. Wait until Spot has fully moved through the doorway and the door has fully closed.



8. When prompted, select the door handle or push point for the reverse side of the door.



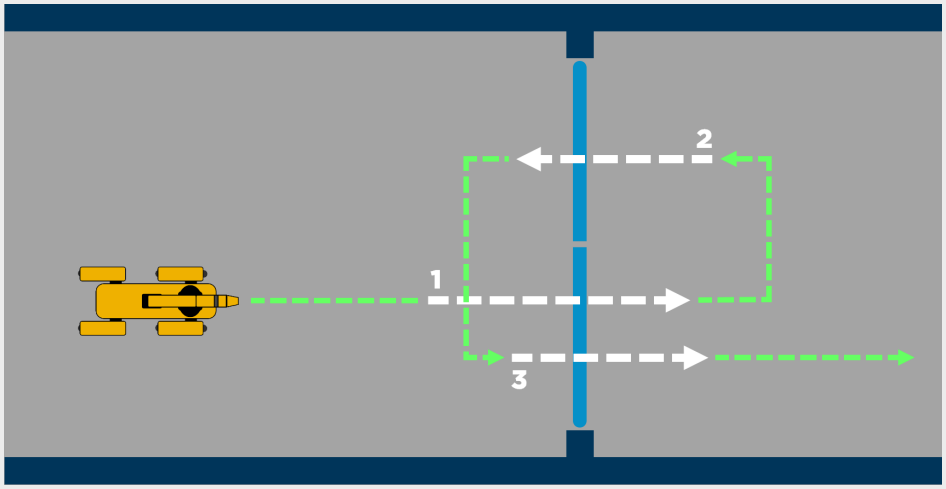
9. Choose the appropriate door settings for the reverse side of the door, then select **Save door settings**.



10. Wait until the success message appears. Select **OKAY**, then continue recording the mission.

NOTICE

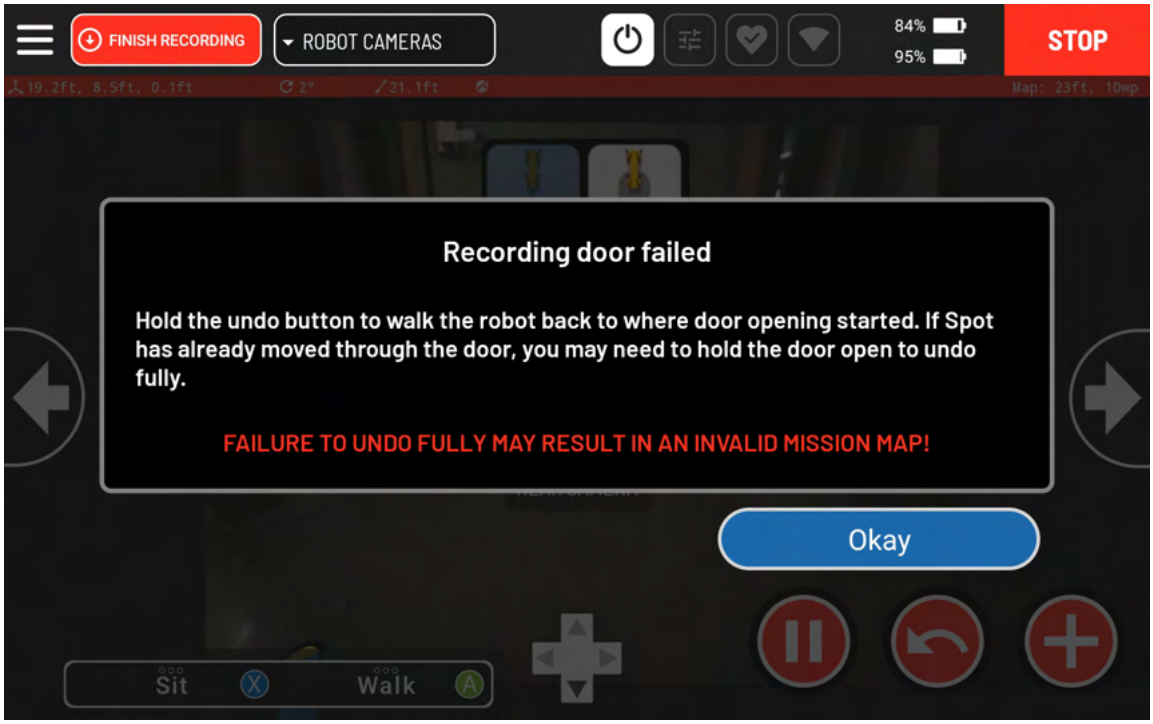
- A single door can be included multiple times in a mission recording. For instance, if the route requires Spot to enter and exit an area through the same door, then two door-opening actions will be recorded.
- Double doors can be treated as two single doors side-by-side. To make your mission more robust, record a loop that doubles back through both halves of the door before continuing (this will require transiting one half of the door twice). On replay, setting **Take shortcuts** to **YES** will simplify the route to a single transit through the door, while allowing Spot to reroute through either side of the door if one side becomes unnavigable.



Example mission route including a double door. The operator records three door-opening actions: one for the south door (1), one to double back through the north door (2), and one to transit the south door again and continue the mission recording (3).

If door opening fails or is cancelled:

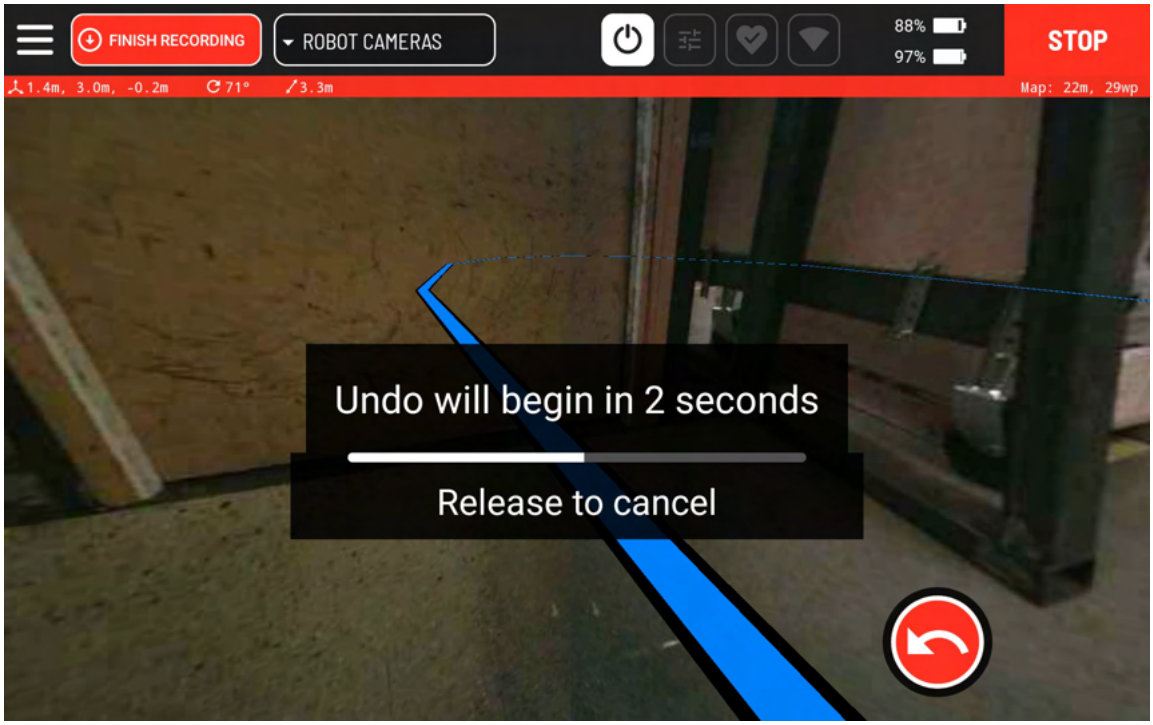
1. During recording, if door opening fails or is canceled, you will see the following prompt:



2. Ensure the door is propped or held open so that Spot can return to the side of the door it started on.

> **CAUTION**
> Always stay 2 meters away from Spot during operation.

3. On the tablet controller, touch and hold ↶ **Undo**.



4. Wait for Spot to return through the door. Release ↶ **Undo** to finalize the undo process, then continue recording the mission.

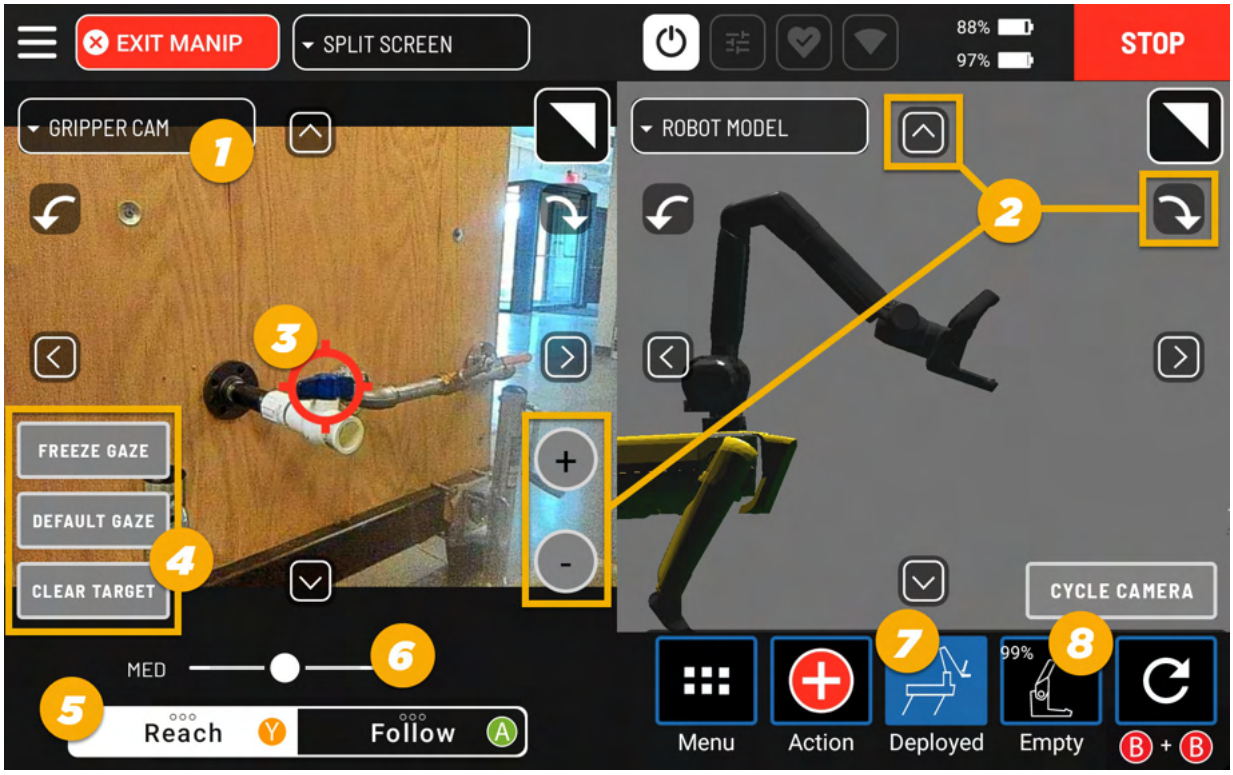
> **NOTICE**
> Failure to fully undo a failed or canceled door-opening action may result in an invalid mission map.

For details on how Spot automatically performs the recorded door-opening actions during an Autowalk mission, see Spot Arm Behavior During Autowalk Missions.

5.7. Operate Arm

When you select **Operate Arm** from the Manipulation Menu:

- Spot moves to the Stand pose.
- The Spot App switches to a split-screen view, to provide greater situational awareness of Spot and Spot Arm.
- **Reach** is activated. Joysticks switch to driving Spot Arm (see Analog Controls and Button Combinations).



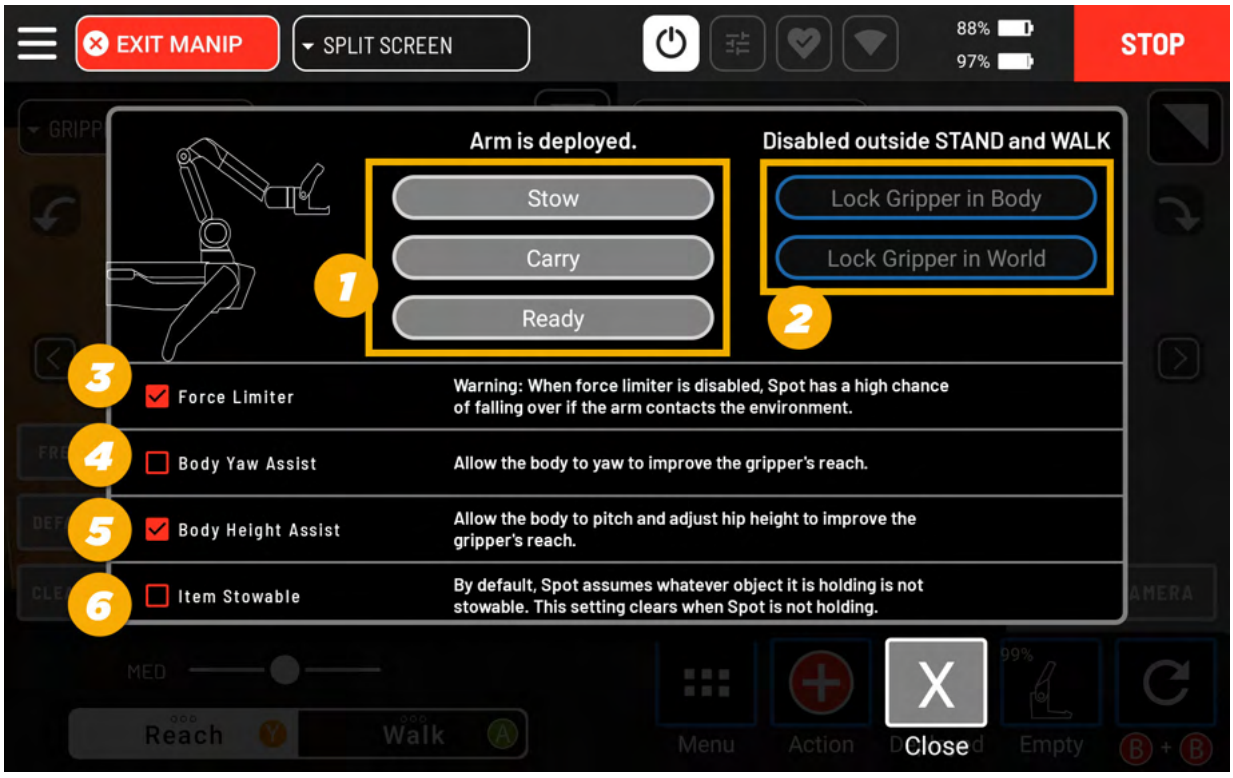
Manual controls for operating Spot Arm.

No.	Control	Description
1	Cameras dropdown	Select from available camera views.
2	Nudge buttons	Fine-tuned controls that adjust the gripper (or Spot, depending on camera view) in small increments: • Move up (^), down (ᵛ), left (<), and right (>). • Roll clockwise (↷) and counterclockwise (↶). • "Zoom" in (+) and out (-) by moving forward and back.
3	Gaze target[1]	Tap the screen to keep the gripper camera pointed at a target.
4	Gaze controls[1]	• FREEZE GAZE: Holds the gripper in its current configuration relative to Spot's body as Spot moves around. • DEFAULT GAZE: Keeps the gripper camera pointed toward the gaze target as Spot moves around. • CLEAR TARGET: Removes the gaze target.

No.	Control	Description
5	**Reach** and **Follow**	When **Reach** is selected, the physical joysticks and buttons on the tablet controller drive Spot Arm while Spot stands in place. When **Follow** is selected, the physical joysticks and buttons drive Spot Arm while Spot slowly follows the trajectory of the gripper.
6	Speed slider	Switch between three maximum speed settings (**SLOW**, **MED**, **FAST**.
7	Manipulator controls	Opens the manipulator controls menu.
8	Gripper controls	Opens the gripper controls menu.

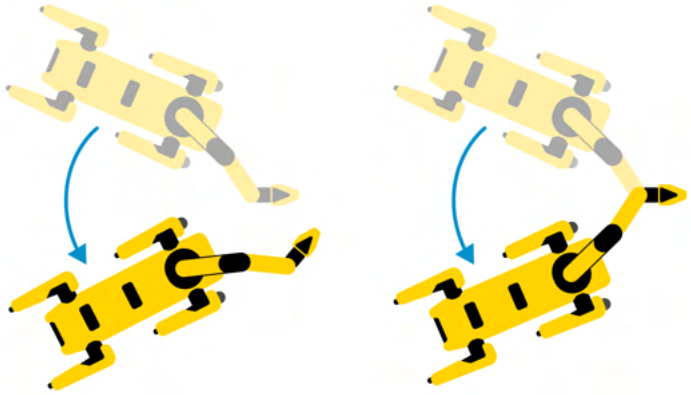
[1]Available only in the **GRIPPER CAM** view.

5.7.1. Manipulator Controls



The manipulator controls menu.

No.	Control	Description
1	Arm poses	Move the arm to the Stow, Carry, or Ready position.

No.	Control	Description
2	Lock gripper to reference frame	When selected, Spot will attempt to keep the gripper at a fixed point in space relative to Spot's own body, or relative to the world around Spot.  ***Lock Gripper in Body*** *(left) vs.* ***Lock Gripper in World*** *(right).*
3	Force Limiter	Toggles the Force Limiter on and off.
4	Body Yaw Assist	When enabled, Spot can yaw its body to extend Spot Arm's range.
5	Body Height Assist	When enabled, Spot can raise, lower, or pitch its body at the hips to extend Spot Arm's range.
6	Item Stowable	When enabled, Spot Arm can move to the Carry position while grasping an object. By default, grasped items are assumed to be not stowable.

5.7.1.1. Force Limiter

The Force Limiter prevents Spot Arm from applying large forces to Spot's body. This reduces the chance that Spot will fall over if Spot Arm collides with an obstacle.

The Force Limiter is on by default. It can be toggled on and off in the manipulator controls menu.

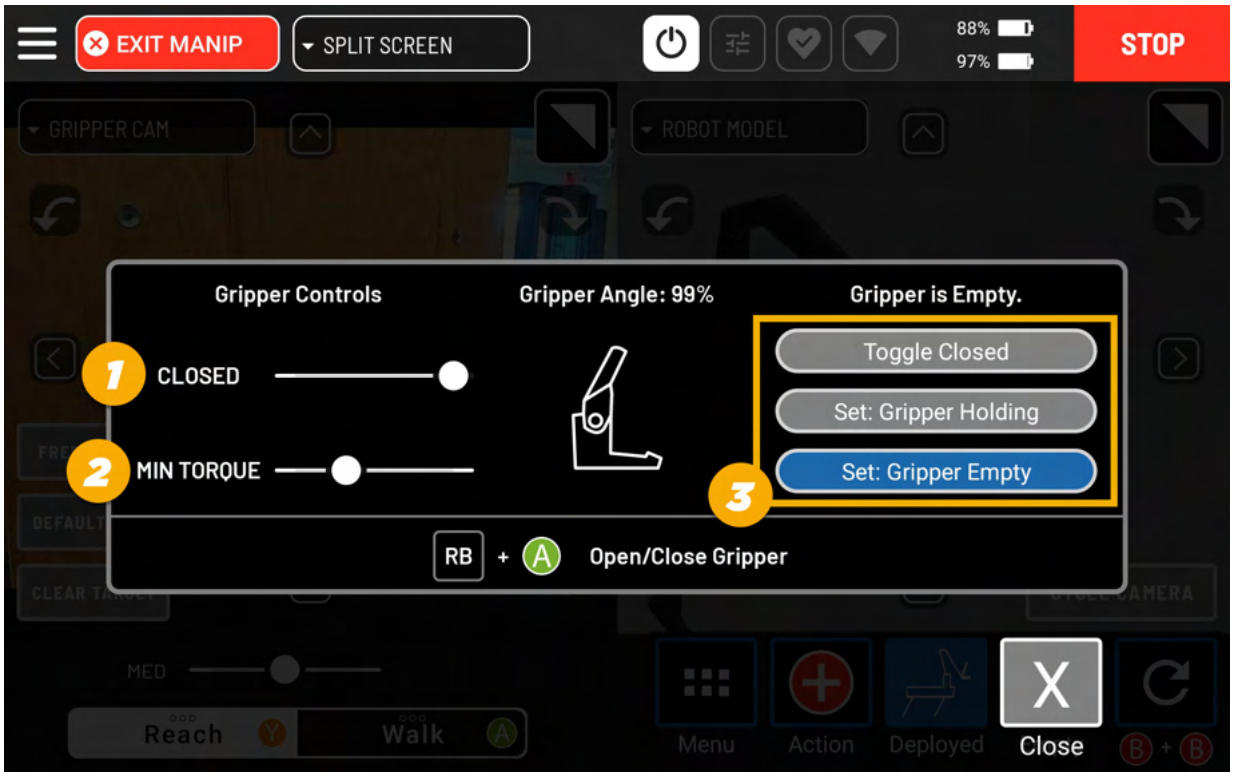
NOTICE

- The Force Limiter will not prevent damage to the environment and is not a safety feature. For details on Spot Arm's mechanical safety features, see Manipulator Motion.
- If Spot walks into an object with Spot Arm outstretched, that object may be damaged.
- The Force Limiter may prevent Spot Arm from lifting and carrying heavier objects.
- Requests to disable the Force Limiter are ignored when carrying out forceful motions such as Constrained Manipulation or Opening Doors.

CAUTION

When the Force Limiter is disabled, contacts between Spot Arm and objects in the world may apply high forces to those objects and/or Spot's body. This may cause damage to Spot, Spot Arm, or the environment.

5.7.2. Gripper Controls



The gripper controls menu.

No.	Control	Description
1	Gripper angle	Slide to adjust the gripper angle from 0% (closed) to 100% (open).
2	Gripper torque	Slide to adjust the amount of force the gripper will apply when grasping.

No.	Control	Description
3	Gripper status	Toggle the gripper open and closed, and set its status to "holding" (grasping an object) or "empty". **CAUTION** Setting the gripper status to "holding" when it is not grasping anything, or to "empty" when it is grasping an object, may result in unpredictable movements of Spot and Spot Arm.

5.8. Arm Pointing

Arm Pointing is an action that uses Spot Arm to aim a camera or sensor at a target in Spot's environment. This behavior can be performed during manual operation or automatically as part of an Autowalk mission.

CAUTION

Spot's obstacle avoidance capability does not extend to Spot Arm.

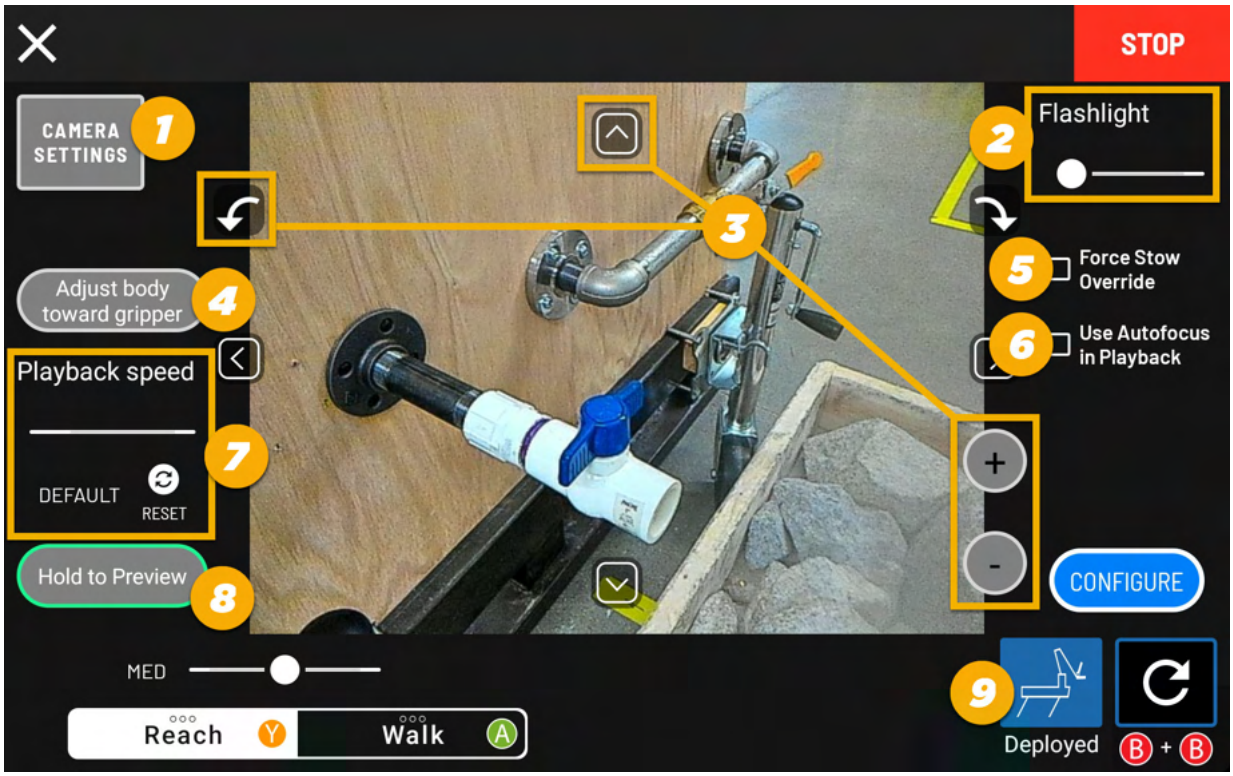
Do not use Arm Pointing in confined spaces, near fragile equipment, or near people.

Always stay 3 meters away from Spot and Spot Arm during operation.

Arm Pointing is ideal for:

- Spot robots that are equipped with Spot Arm, but not Spot Cam+ or other cameras.
- Environments where Spot cannot position other cameras with direct line-of-sight to an inspection target.
- Environments where Spot cannot move its body close enough to an inspection target to capture a useful image with other cameras.

5.8.1. Arm Pointing Controls and Settings



Arm Pointing controls and settings.

No.	Control	Description
1	**CAMERA SETTINGS**	Opens and closes the settings panel for the gripper camera. Settings include: • Resolution • Auto Exposure • Auto Focus • Gain • Brightness • Contrast • Saturation • HDR
2	**Nudge buttons**	Fine-tuned controls that adjust the gripper in small increments: • Move up (˄), down (˅), left (˂), and right (˃). • Roll clockwise (↷) and counterclockwise (↶). • “Zoom” in (**+**) and out (**-**) by moving forward and back.

No.	Control	Description
3	**Flashlight**	Adjusts the brightness of the gripper flashlight.
4	**Adjust body toward gripper**	Moves Spot's body toward the gripper, keeping the gripper in place in the world. **NOTICE** Selecting a gait and driving Spot during Arm Pointing will also keep the gripper fixed in the world.
5	**Force Stow Override**[1]	Forces the arm to stow and redeploy in between multiple captures at the same location. Enabling this will improve the accuracy and consistency of the arm's positioning for subsequent captures.
6	**Use Autofocus in Playback**	By default, the mission records the focus value at the time the action was recorded, regardless of whether you were using manual focus or autofocus at the time. Select **Use Autofocus in Playback** to force the camera to autofocus each time the action is replayed. **NOTICE** Autofocus takes longer and is less reliable in many situations. It is best for images that must be captured with the gripper camera close to the target or where the distance to the target varies significantly between captures. Capturing the image from farther away makes the result less sensitive to differences in robot and arm positioning and focus values.
7	**Playback speed**[1]	Adjusts how quickly the arm will move during playback.
8	**Hold to Preview**[1]	Stows, then moves the arm to the current position as it would be deployed during mission replay. **To preview an Arm Pointing action:** 1. Touch-and-hold on the **Hold to Preview** button. The arm will stow, then begin to deploy back to the current inspection point. 2. Release the button at any time to pause the preview. Touch-and-hold again to resume. 3. Moving Spot or Spot Arm in any way will exit the preview and set the inspection point to the current position.

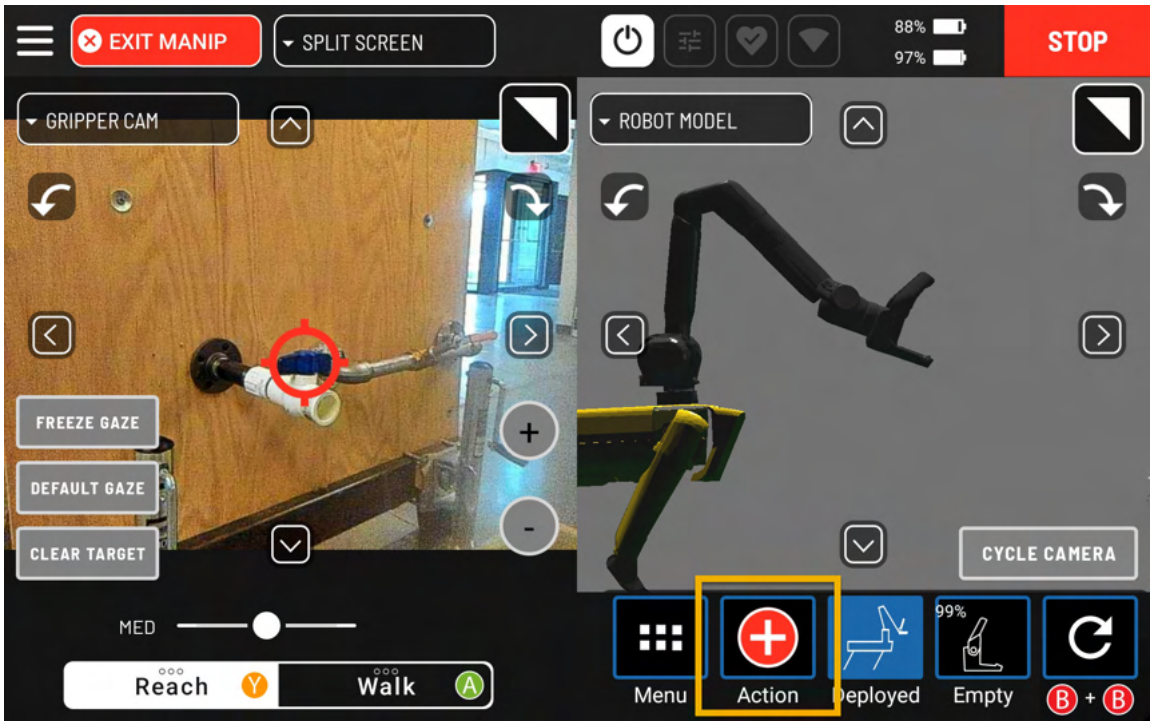
No.	Control	Description
9	**Enable body height assist**	Enabled by default. Allows Spot to adjust its pitch and hip height as the gripper is being positioned. Disabling limits the maximum height the gripper can reach, but ensures as little extraneous movement as possible. This setting is accessed from the manipulator controls menu (see Operate Arm).

[1]Only available when recording an Autowalk mission.

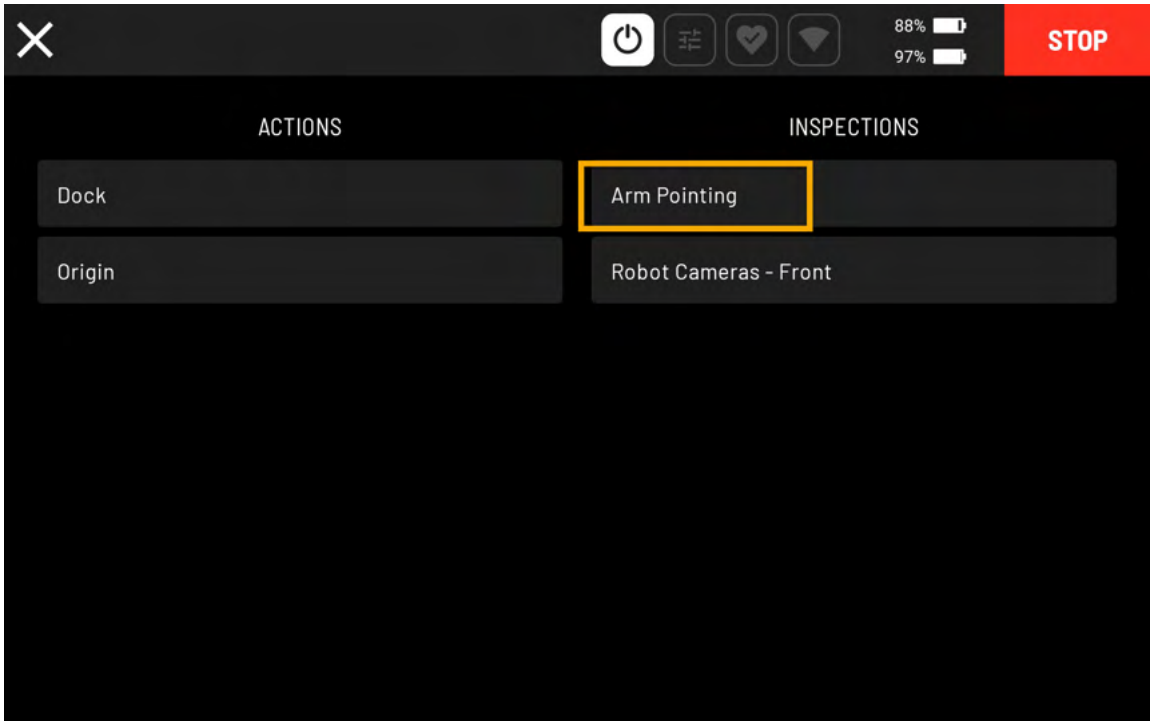
5.8.2. Arm Pointing During Manual Operation

To perform an Arm Pointing action during manual operation:

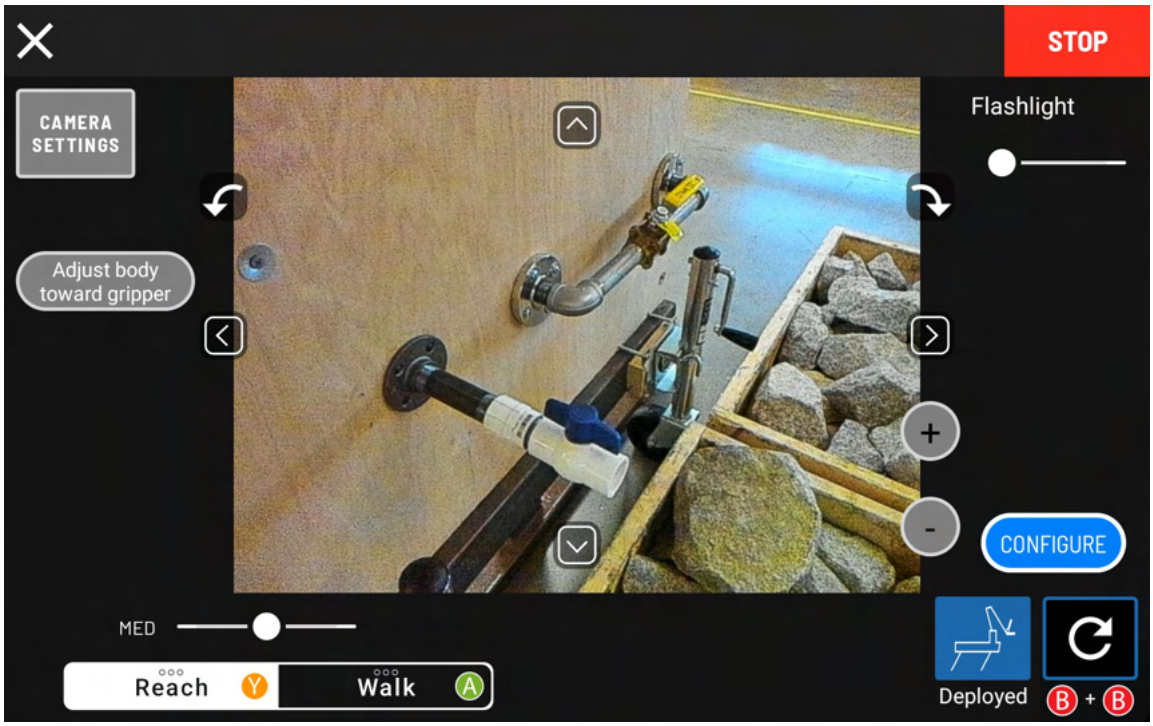
1. While in Manipulation mode mode, select **Add Action**.



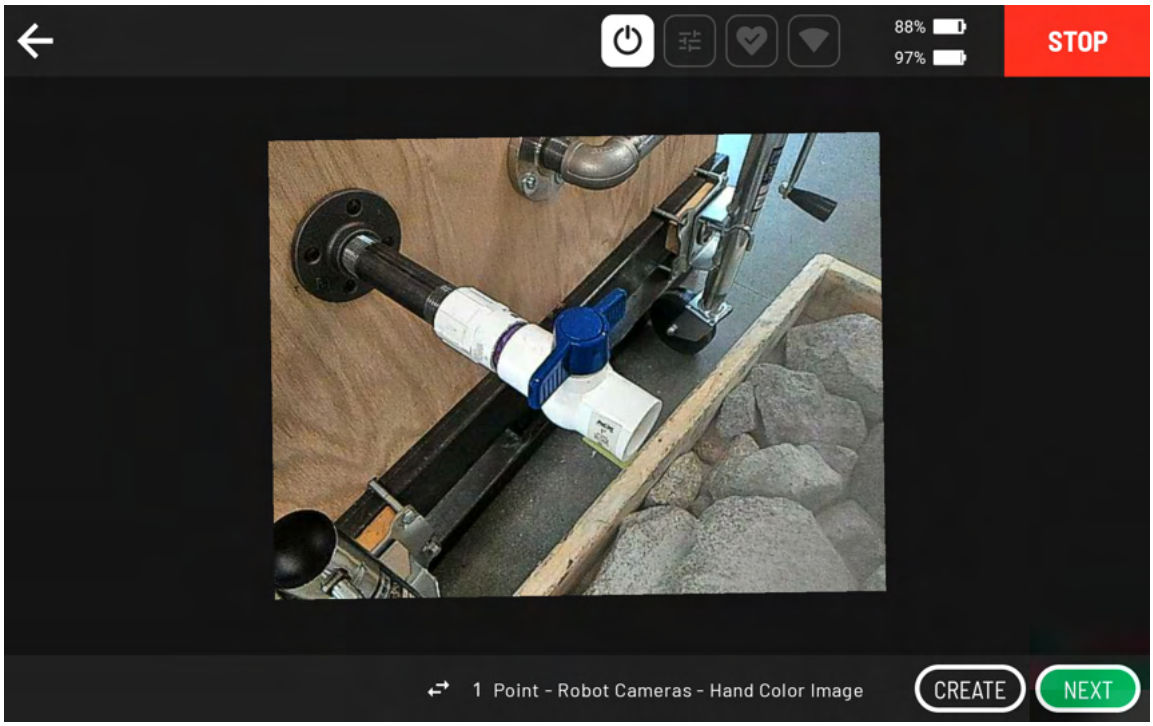
2. On the **ACTIONS** tab, select **Arm Pointing**.



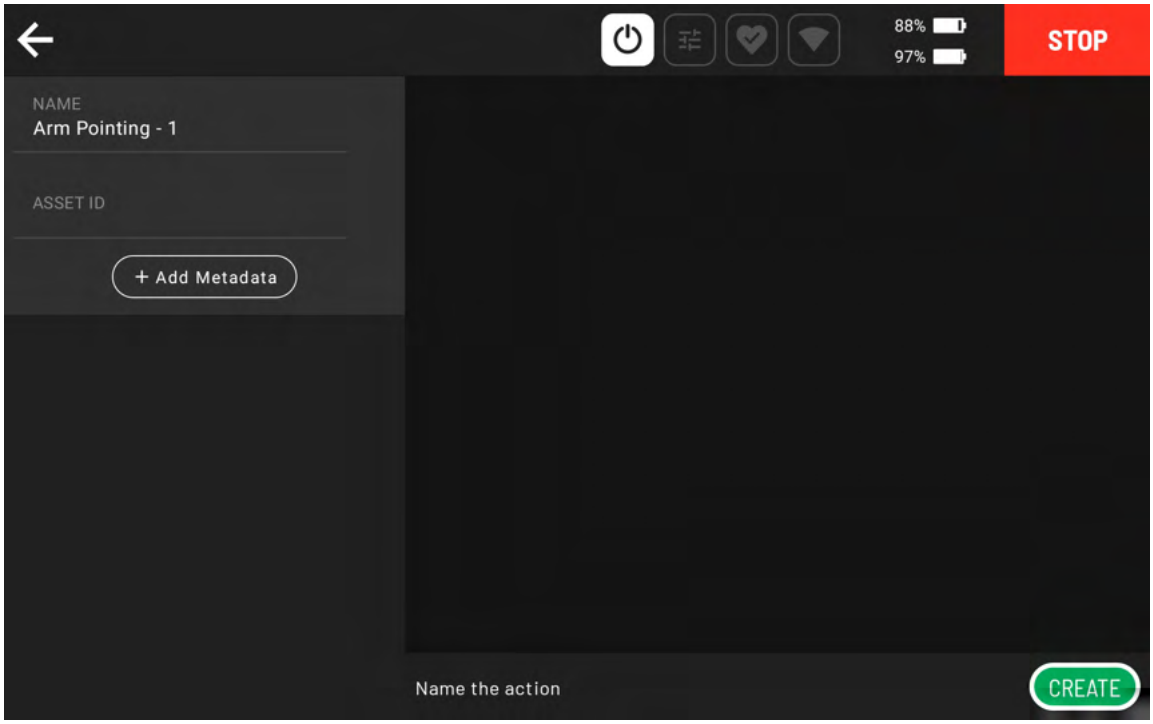
3. Use the joysticks and/or on-screen controls to point Spot Arm at the target and configure the image to be captured, then select **CONFIGURE**.



4. Tap the label below the image to switch between available sensor modes. Then select **CREATE** to save the image as-is, or select **NEXT** to add metadata to the image before saving.



5. Add metadata tags, then select **CREATE** to save the image with metadata.



6. Select **ADD ANOTHER** to perform additional inspections at the same location, or select **ALL DONE** to complete the action.

5.8.3. Arm Pointing in Autowalk

For best results when adding an Arm Pointing action to an Autowalk mission:

- Avoid extreme arm positions where joints are at their limits. Such positions are difficult to replay accurately and may result in collisions or the robot failing to perform the action.
- Keep the gripper camera at least 30 cm from the target and nearby objects. During replay, slight differences in arm position may result in collisions or poor image quality if the gripper is too close to the target.
- Use **Hold to Preview** to check how Spot Arm will reproduce the gripper position during mission replay.

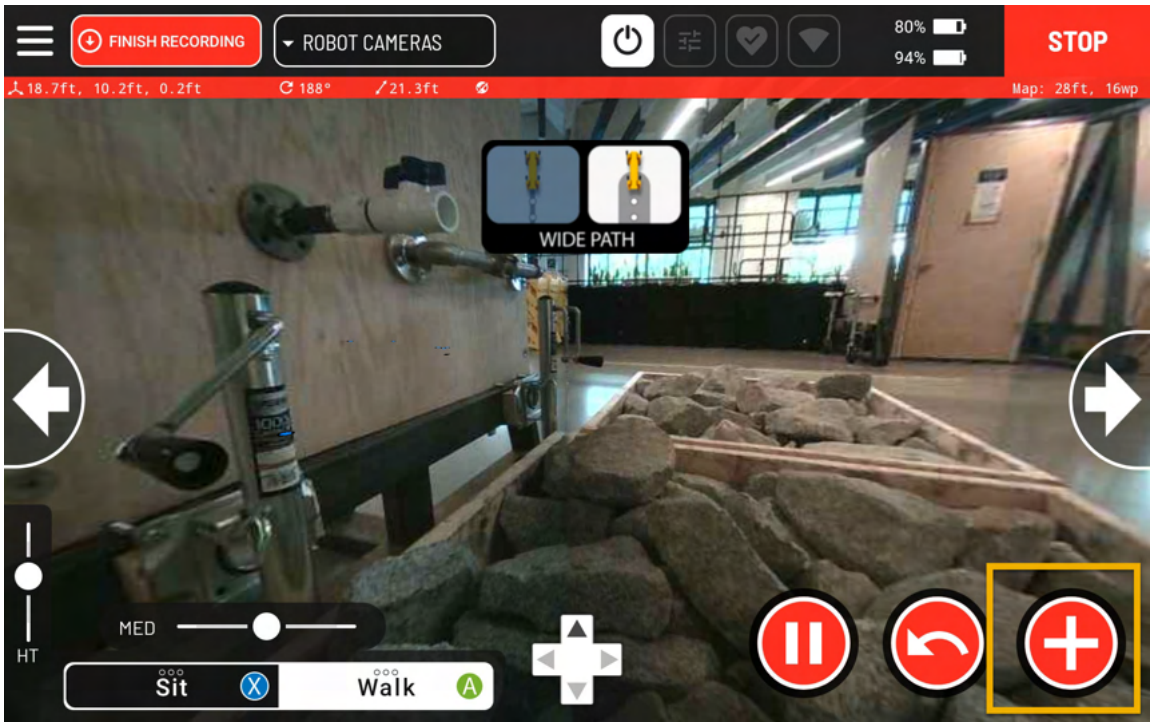
> **CAUTION**
>
> When replaying an Arm Pointing action, the arm will recreate the final pose, but will not replicate the exact path through three-dimensional space that was used to get it there during recording.
>
> Arm Pointing actions that place the gripper into confined spaces, such as snaking through a gap or reaching behind an object, may result in collisions that could damage Spot, Spot Arm, or objects in the environment.

- To capture fine details, select **CAMERA SETTINGS** and increase the image resolution rather than moving the gripper closer to the target.

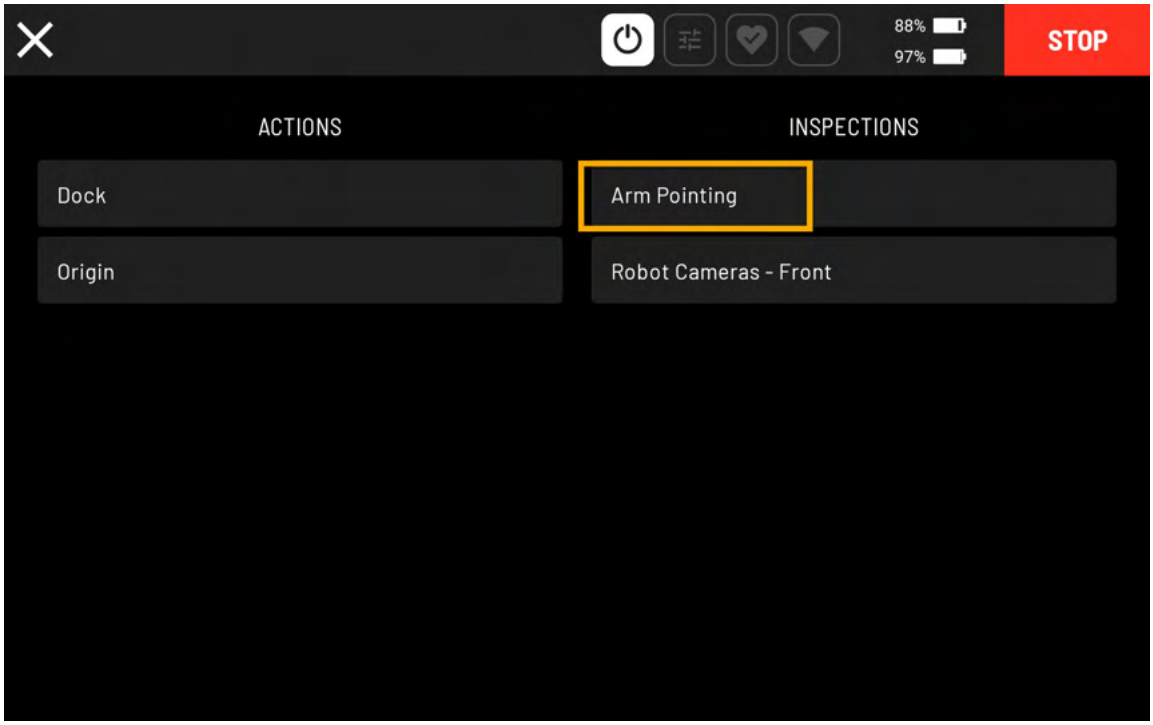
5.8.3.1. Record an Arm Pointing Action

To add an Arm Pointing action to an Autowalk mission:

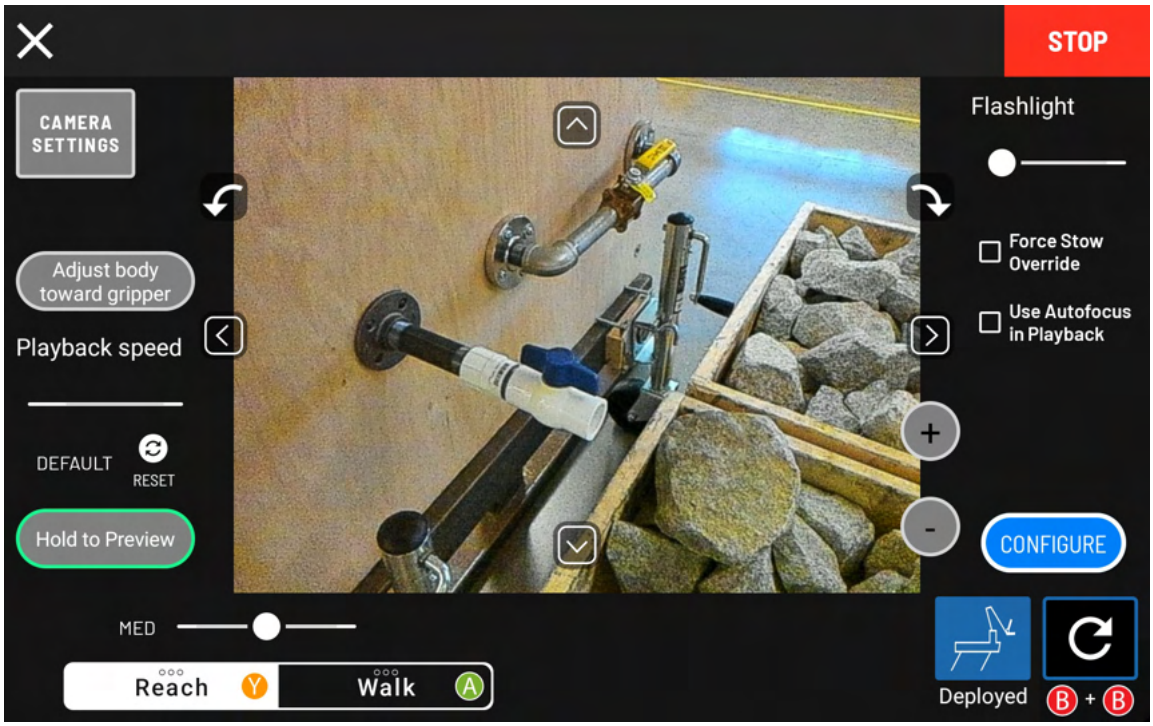
1. Begin recording an Autowalk mission (see). For instructions, refer to documentation in the Boston Dynamics Support Center (see Appendix A: Supplemental Information).
2. Select **Add Action**.



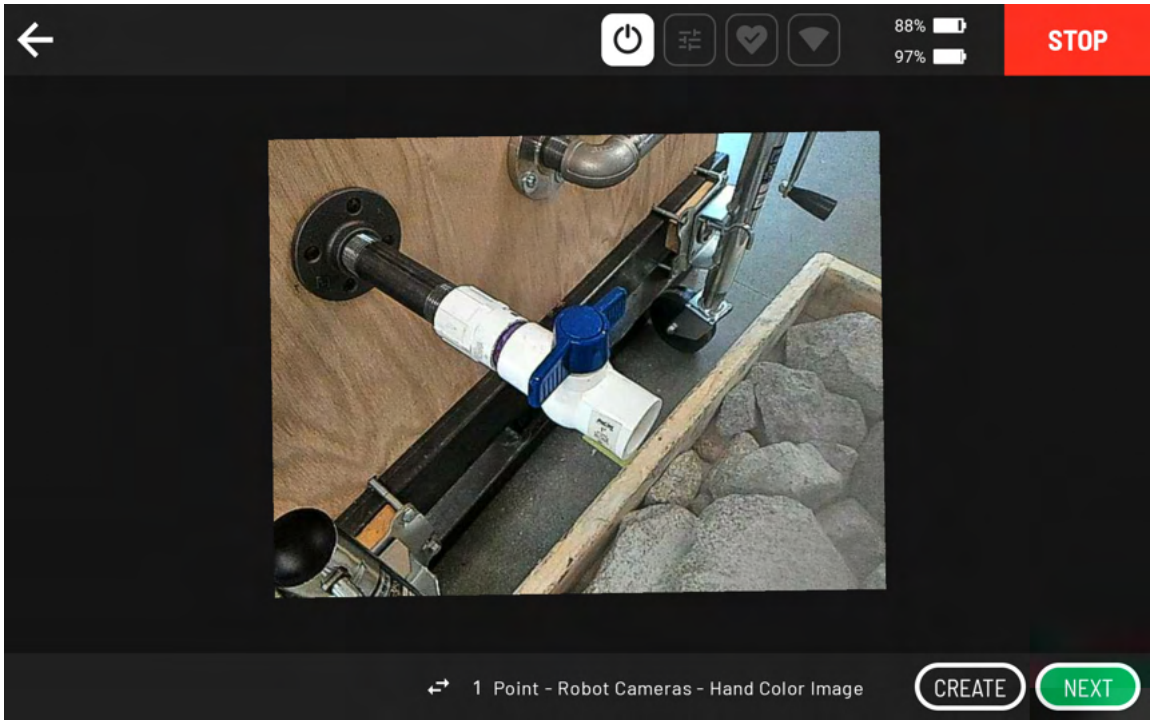
3. On the **ACTIONS** tab, select **Arm Pointing**.



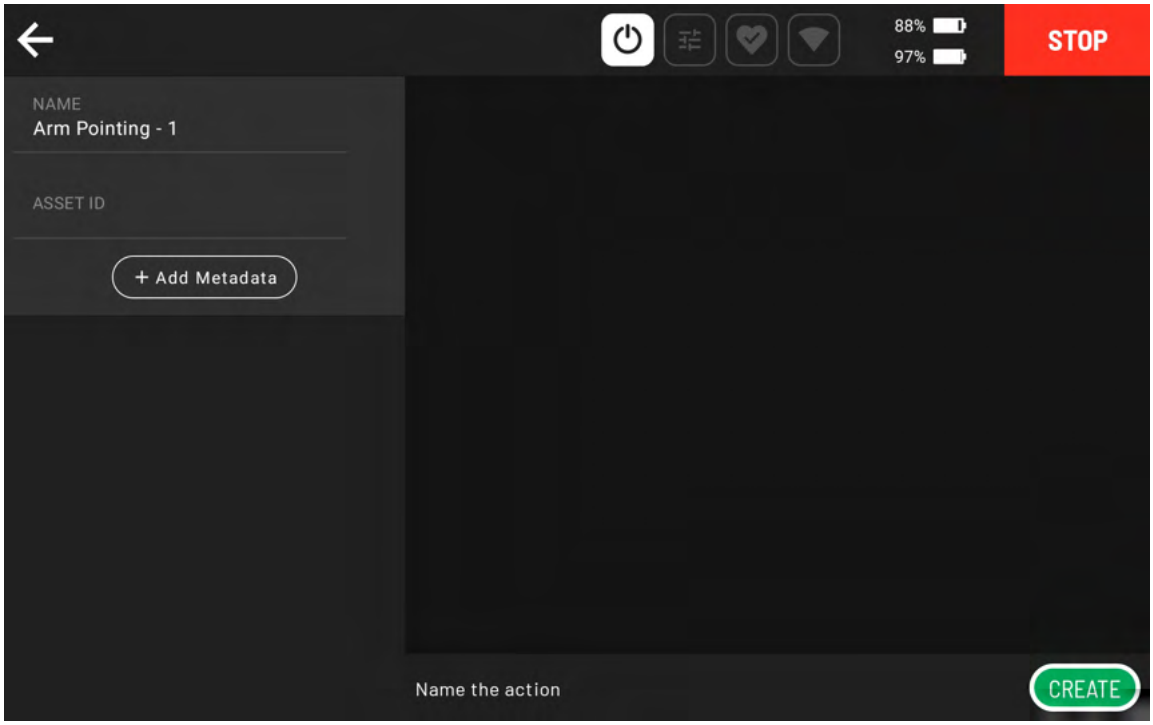
4. Use the joysticks and/or on-screen controls to point Spot Arm at the target and configure the image to be captured, then select **CONFIGURE**.



5. Tap the label below the image to switch between available sensor modes. Then select **CREATE** to save the image as-is, or select **NEXT** to add metadata to the image before saving.



6. Add metadata tags, then select **CREATE** to save the image with metadata.



7. Select **ADD ANOTHER** to perform additional inspections at the same location, or select **ALL DONE** to complete the action.
8. Wait for the arm to stow, then continue recording the mission.

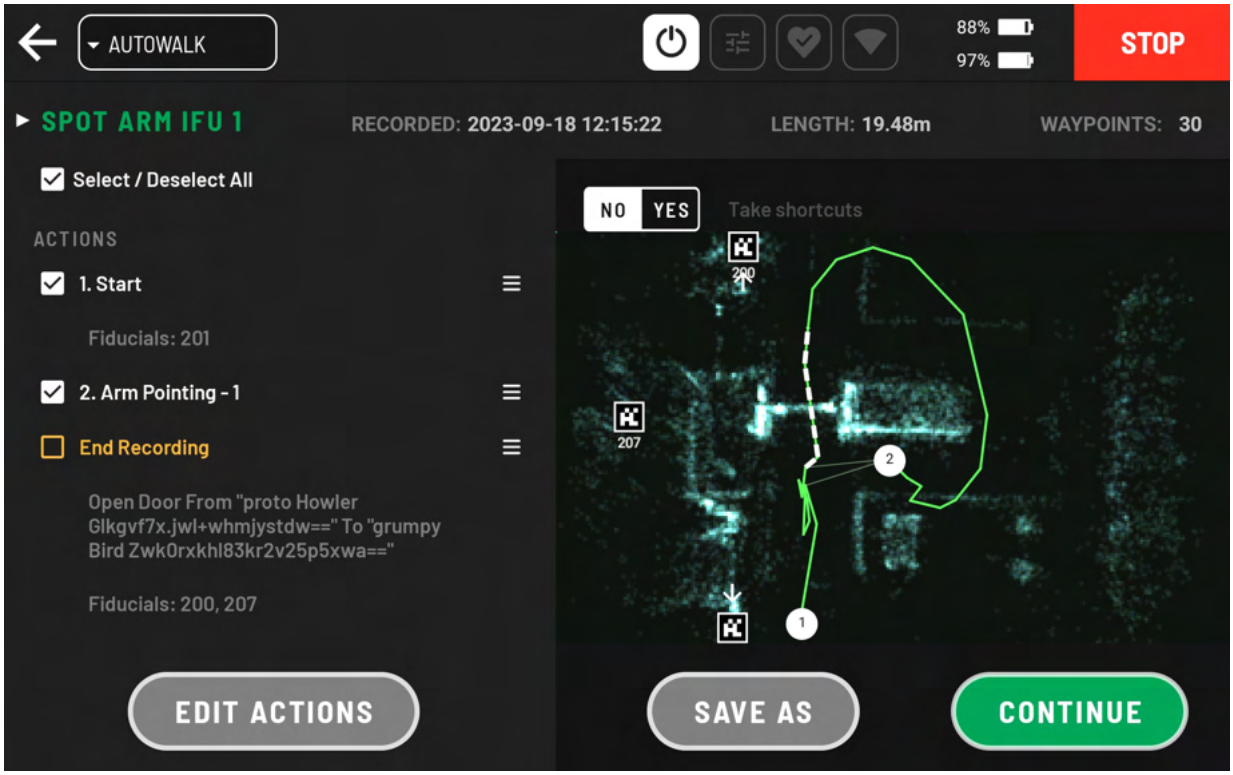
5.9. Spot Arm Behavior During Autowalk Missions

If an Autowalk mission includes actions such as Opening Doors or Arm Pointing, Spot with Spot Arm will automatically perform these behaviors during mission replay.

Spot with Spot Arm will not reproduce other commands that may have been input during mission recording, such as commands to deploy, operate, or stow the arm that were not part of an action. Only the recorded actions will be performed.

5.9.1. Door Opening During Mission Replay

Each door-opening action is represented in Autowalk maps as a dotted white line overlaid on the route segment that traverses the door.

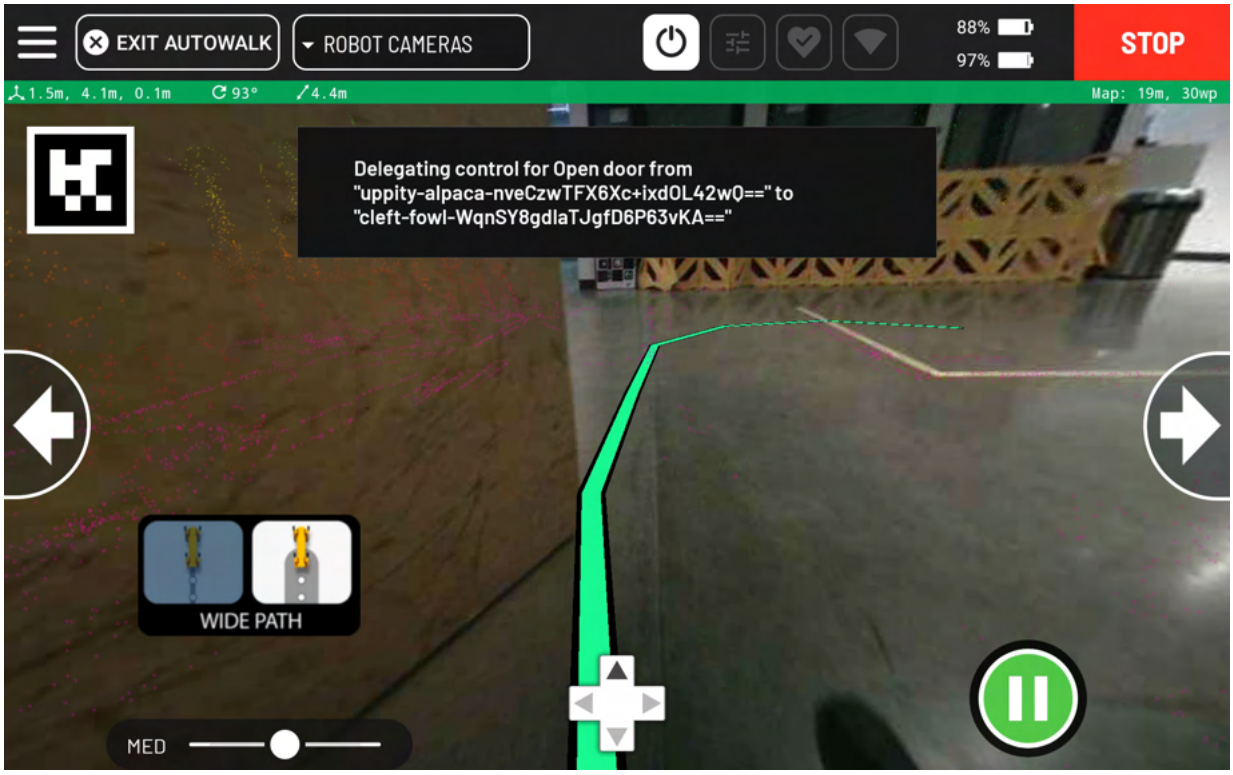


Preview of an Autowalk mission route that includes a door-opening action.

During mission replay, Spot will open doors automatically as needed.

If a door is already open, Spot will walk through the doorway and continue the mission.

If part of the mission route is blocked, Spot may reroute through a door in either direction to reach its destination.



Spot automatically opening a door during an Autowalk mission.

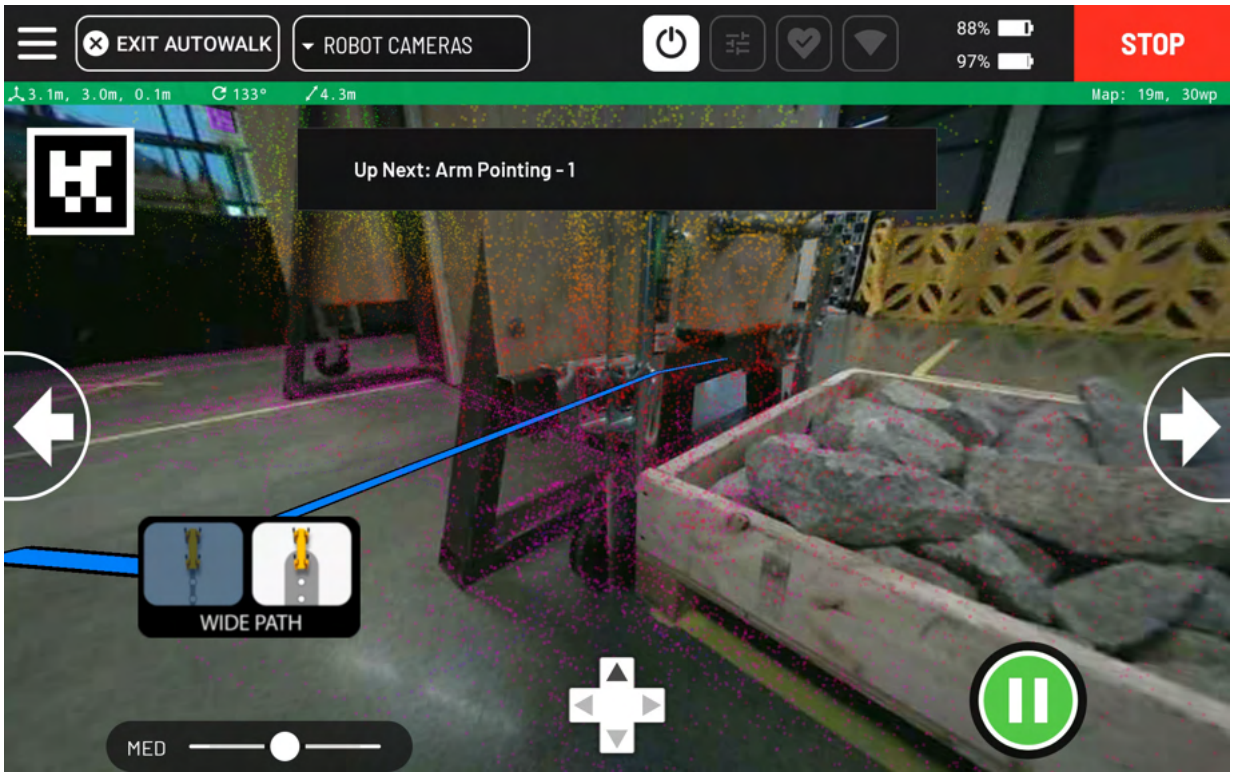
WARNING

Spot cannot detect people or obstacles on the other side of a closed door. Unexpected hazards may occur during or after door opening.

Doorways are constrained spaces where Spot's obstacle avoidance system may not be able to prevent collisions with nearby people or objects.

- Do not attempt to open a door that Spot is already opening.
- Do not stand in or near a doorway that Spot is traversing, or attempt to pass Spot through a doorway.
- Always stay 3 meters away from Spot and Spot Arm during operation.

5.9.2. Arm Pointing During Mission Replay



Spot automatically performing an Arm Pointing action during an Autowalk mission.

When Spot with Spot Arm replays an Arm Pointing action during an Autowalk mission, it will:

1. Walk to the waypoint where the action was recorded.
2. Reproduce the gripper camera settings that were used during recording, including the flashlight.
3. Reposition its feet in a wide stance.
4. Deploy the arm to the recorded inspection point (may include adjustments to body position).

> **CAUTION**
>
> When replaying an Arm Pointing action, the arm will recreate the final pose, but will not replicate the exact path through three-dimensional space that was used to get it there during recording.
>
> Arm Pointing actions that place the gripper into confined spaces, such as snaking through a gap or reaching behind an object, may result in collisions that could damage Spot, Spot Arm, or objects in the environment.

5. Capture data.
6. Reset the gripper camera settings.
7. Perform any additional captures recorded at the same location.
8. Stow the arm and continue the mission.

6. Maintenance

6.1. Service and Repair

Do not attempt to service or repair Spot or Spot Arm yourself. If errors or other issues persist during robot operation, Spot and Spot Arm may need attention from Boston Dynamics Support engineers. Include the following information when contacting Support:

- Spot serial number
- Description of the issue

To contact Boston Dynamics Support, visit: https://support.bostondynamics.com/s/contactsupport.

6.2. Visual Inspection of Spot Arm

Periodic inspection of Spot Arm may identify damage that could generate hazardous conditions.

To conduct a visual inspection of Spot Arm:

1. Move the manipulator to the stowed position.
2. Check that the elbow and shoulder joints are able to fold completely.
3. Check that revolving joints do not present signs of misalignment, wear, or damage.
4. Check that manipulator and gripper outer coverings do not present visible evidence of damage.
5. If any evidence of damage is found, contact Boston Dynamics Support.

While conducting the visual inspection, always follow safe handling guidance as described in Safe Handling.

7. Declarations and Marking

Spot Arm is a partly completed machinery as defined in Directive 2006/42/EC Art. 2(g), valid in the E.U.

7.1. EU Declaration of Incorporation

This document is prepared in accordance to Machinery Directive 2006/42/EC, Annex II 1-B — Originally authored in English.

Manufacturer:	Boston Dynamics, Inc 200 Smith Street Waltham, MA 02451 USA	Person authorised to compile the technical file established in the community:	Boston Dynamics GmbH Alexander-Fleming-Ring 57 65428 Rüsselsheim Germany

Description and Identification of the Machinery:

Product and function: "Spot + Spot Arm" is a robot comprised of a mobile unit equipped with four articulated limbs for locomotion with a manipulator mounted on top, controlled by a shared controller.

The function is determined by the completed machine (application and intended use).

Robot Name	Model	Serial Number (S/N)
Spot + Spot Arm	04-00143531-101 04-00143531-501 04-00143531-711	BD-33390001 and higher

It is declared that the product, for what is supplied, shall only be put into service upon being integrated into a final complete machine (robot application), which conforms with the provisions of the Directive 2006/42/EC and amend. (MD) and other applicable Directives, and with the regulations transposing EU Directives into national law. Compliance with all essential requirements of Directive 2006/42/EC relies on the correct incorporation conditions into a specific robot application and a final risk assessment.

The following Essential Safety and Health Requirements (EHSR) and supplementary requirements of Annex I of the Machinery Directive 2006/42/EC and amend. (MD), have been applied and fulfilled:

1.1.2, 1.1.3, 1.1.5, 1.2.1, 1.2.2, 1.2.3, 1.3.2, 1.3.4, 1.3.7, 1.5.1, 1.5.2, 1.5.6, 1.5.10, 1.5.11, 1.5.12, 1.7.1, 1.7.2, 1.7.3, 1.7.4, 3.5.1

Conformity to other directives: It is declared that the above product, for what is supplied, fulfills all the relevant provisions of the following directives, according to which the product is CE marked:

EMC Directive 2014/30/EU and amend.("EMCD"), Radio Equipment Directive 2014/53/EU and amend. ("RED").

Harmonized Standards Used, as referred to in:

EMCD: EN 61000-6-4:2007/A1:2011, EN 61000-6-2:2005/AC:2005

RED: ETSI EN 301 489-1 V2.2.1 (2019), ETSI EN 301 489-17 V3.2.2 (2020), EN 55032:2012

Other Technical Standards Used:

EN ISO 12100:2010, EN 60204-1:2018, EN IEC 62133-2:2017, EN IEC 60825-1:2014/A11:2020

Boston Dynamics shall transmit relevant information about the partly completed machinery in response to a reasoned request by the national authorities.

Waltham, MA (USA)	Authorised Representative
October 22, 2024	Jason P Fiorillo, Chief Legal Officer

8. Appendix A: Supplemental Information

Additional information and resources about Spot are available online at the following URLs:

Resource	Section	URL
Spot Instructions for Use	1.1 2.3 2.4 2.7.1 2.7.3 3.2 4.1	https://support.bostondynamics.com/s/spot-product-safety
Spot Power Supply Information for Use	3.3.1	https://support.bostondynamics.com/s/spot-product-safety
About the Spot Industrial Inspection Package	5.1	https://support.bostondynamics.com/s/article/About-the-Spot-Industrial-Inspection-Package-72008
Orbit Administration and Settings	5.1	https://support.bostondynamics.com/s/article/Orbit-Administration-and-Settings-71290
Orbit Operator controls	5.1	https://support.bostondynamics.com/s/article/Orbit-Operator-Controls-71298
Moving object detection	5.6	https://support.bostondynamics.com/s/article/Moving-Object-Detection-72044
Door manipulation with the Spot Arm	5.6	https://support.bostondynamics.com/s/article/Door-Manipulation-with-the-Spot-Arm-72021
What Is Autowalk?	5.6 Arm Pointing	https://support.bostondynamics.com/s/article/What-Is-Autowalk-49934