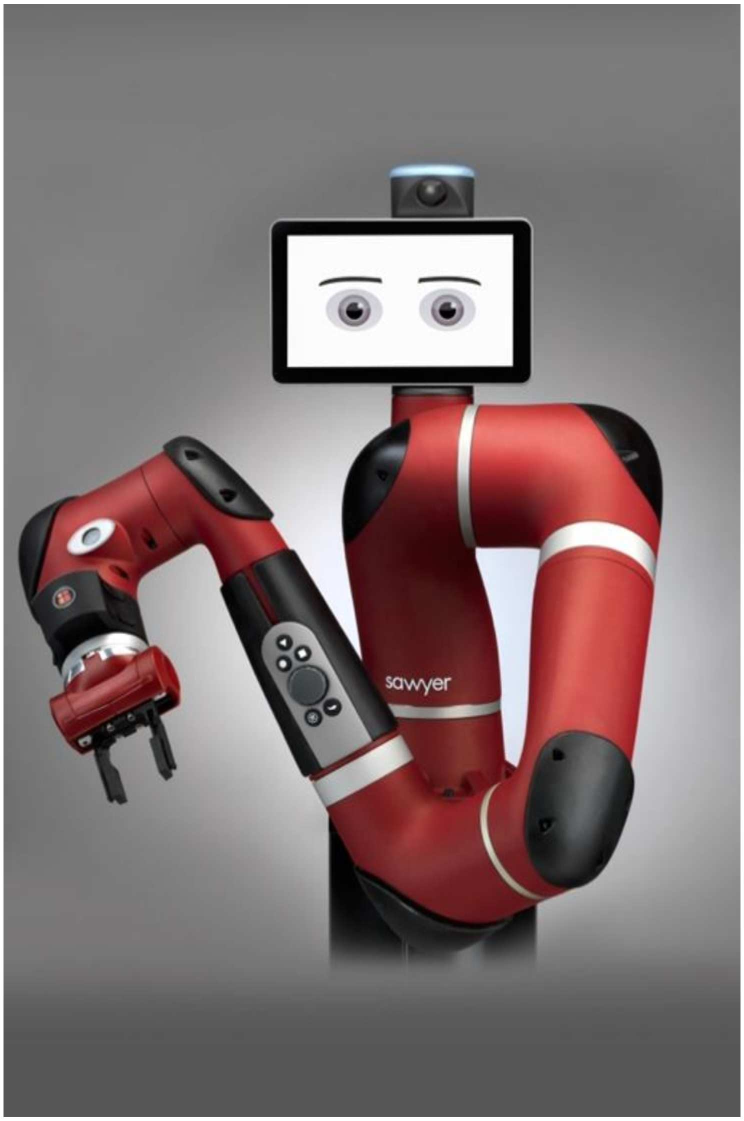
# Sawyer Advanced Specifications

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# Sawyer Advanced Specifications

## Technical Specification Table

| | |
|---|---|
| **Reach** | 1260 mm |
| **Payload** | 4 kg |
| **Task Repeatability** | 0.1 mm |
| **Max Tool Speed** | 2 m/sec |
| **Typical Task Tool Speed** | 1 m/sec |
| **DOF** | 7 |
| **Operating Temperature** | 0ºC – 40ºC, 80% Relative Humidity |
| **Robot Weight** | 19 kg |
| **Power Consumption** | 700 watts |
| **Power Requirements** | 100-240 VAC, 47-63 Hz, 4A Max |
| **Joint Ranges** | J0 – J5: 350 degrees, J6: 540 degrees |
| **I/O Ports (Controller)** | 8 digital in / 8 digital out |
| **I/O Power** | 24 volts, 2 amps |
| **I/O End of Arm** | 4 digital in / 2 digital out / 2 analog in (enabled summer 2016) |
| **Communication** | Modbus Remote I/O, PLC |
| **Controller Cord Length** | 2 M |
| **IP Class** | 54 |
| **Collaboration** | ISO 10218-1:2011 |

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## Shipping Weights and Dimensions

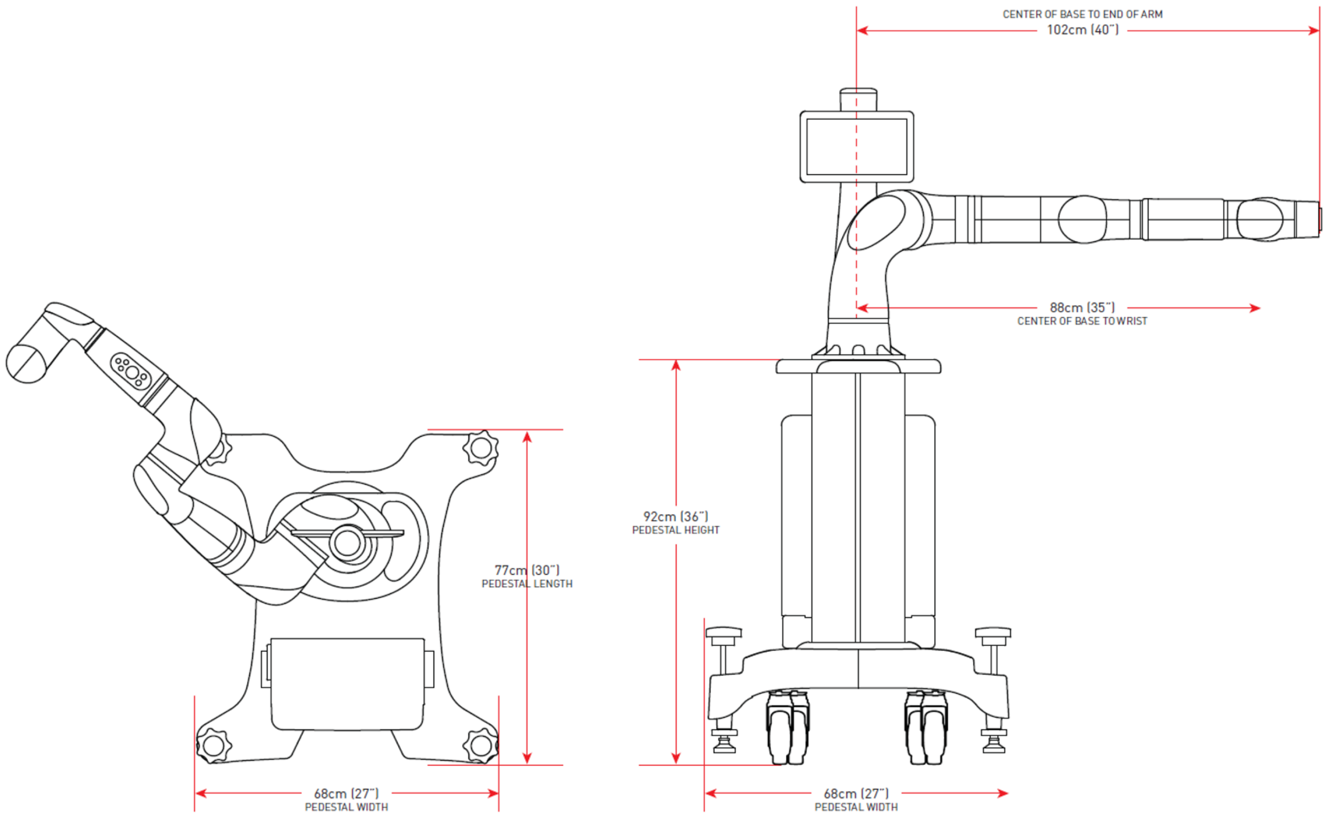
| | Length (in) | Width (in) | Height (in) | Gross Wt (lb) | Net Wt (lb) |
|---|---|---|---|---|---|
| **Robot Box** | 35 | 20 | 20 | 48 | 58 |
| **Controller Box** | 27 | 13 | 20 | 45 | 55 |
| **Accessory Box** | 23 | 26 | 20 | N/A | 13 |
| **Pedestal Crate** | 36 | 48 | 19 | 220 | 250 |
| **Total** | 48 | 39 | 39 | N/A | 381 |

# Drawings

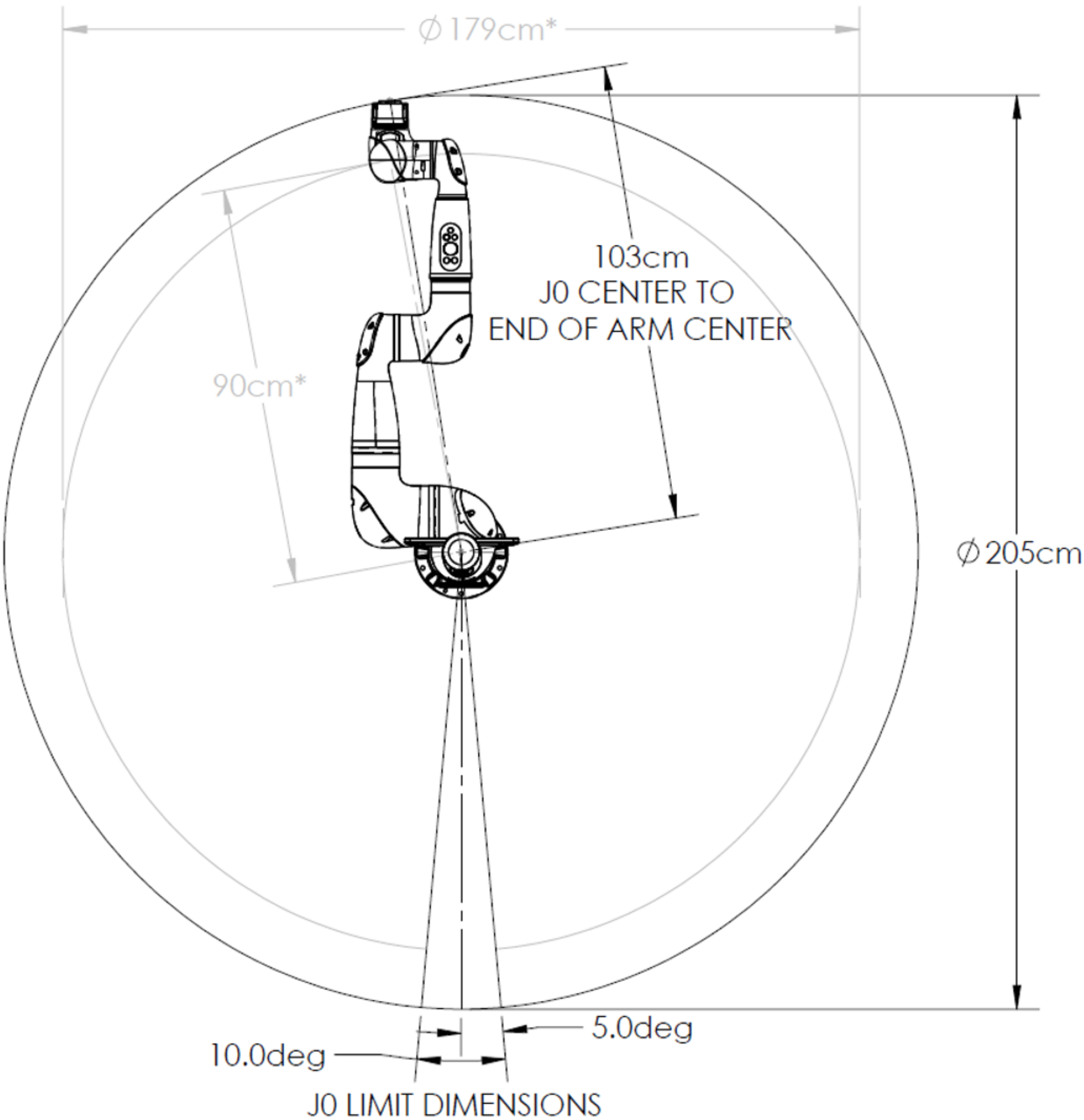
Please follow following links for latest Sawyer drawings and workspace guidelines

http://mfg.rethinkrobotics.com/wiki/Workspace_Guidelines#tab=Sawyer
http://mfg.rethinkrobotics.com/wiki/Robot_Hardware#tab=Sawyer

## Full System

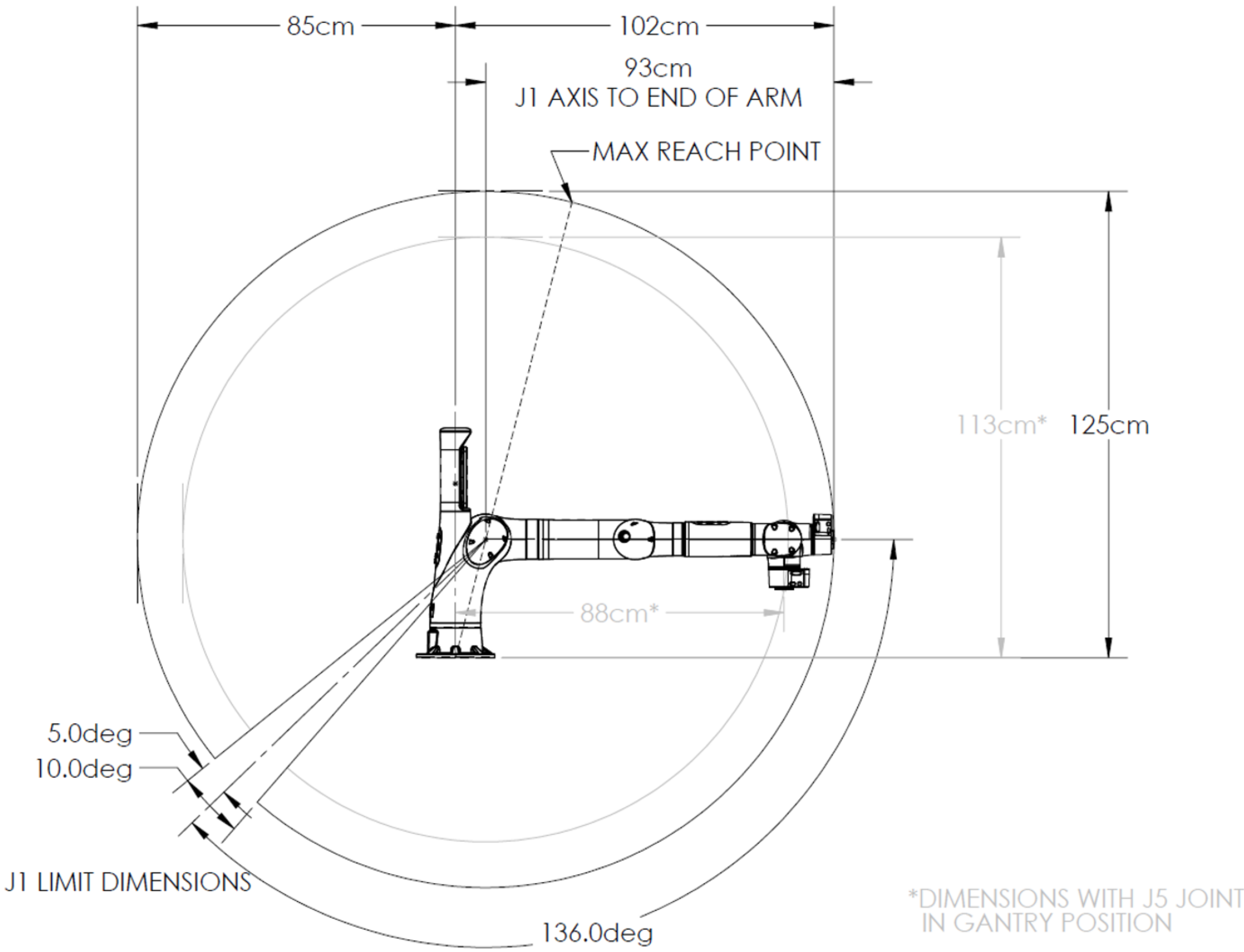


## Top View



∅179cm*
103cm
J0 CENTER TO
END OF ARM CENTER
90cm*
∅205cm
5.0deg
10.0deg
J0 LIMIT DIMENSIONS

## Side View

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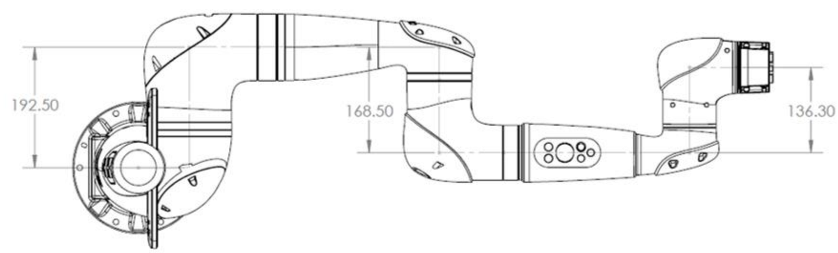
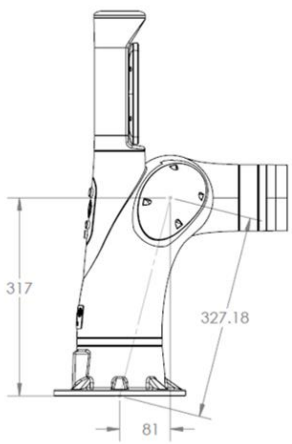
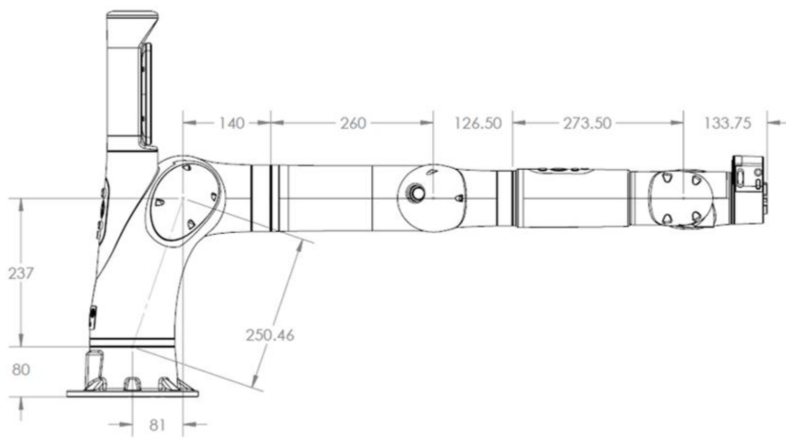
# Link Lengths

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# Sawyer Field Replaceable Unit (FRU) Price List

| Part # | Item | MFG List Price |
|---|---|---|
| **70001** | ROBOT FRU | $21,750 |
| **70002** | CONTROL BOX FRU | $7,250 |
| **70003** | CUFF SWITCH ASSEMBLY FRU KIT | $125 |
| **70004** | LCD SCREEN FRU KIT | $650 |
| **70005** | NAVIGATOR FRU KIT | $250 |
| **70006** | TOOL PLATE FRU KIT | $125 |
| **70007** | MOXA E1212 FRU KIT | $400 |
| **70008** | ESTOP FRU KIT | $175 |
| **70009** | L0 CAP KIT | $20 |
| **70010** | L1 CAP KIT | $60 |
| **70011** | L2 CAP AND PAD KIT | $60 |
| **70012** | L3 CAP AND PAD KIT | $60 |
| **70013** | L4 PAD KIT | $60 |
| **70014** | J5 PAD KIT | $50 |
| **70015** | L5 PAD KIT | $50 |

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# Safety Strategy

http://mfg.rethinkrobotics.com/wiki/Safety

## Collaborative Robots

TS 15066 defines a collaborative robot as a robot that is purposely designed for work in direct cooperation with a human within a defined workspace. Today, most collaborative robots are working in situations where a person periodically has to approach the robot area for reasons such as:

- replenishing the work cell with new parts to process
- taking away finished products
- perform maintenance operation on equipment that the robot is tending (e.g. lubricate a piece of equipment)
- resolve issues, such as a clearing a jam or correcting a part presentation issue.

## ISO 10218/R15.06 and TS15066 Categories

Collaborative robot applications meet the requirements of ISO 10218/R15.06 and TS15066 by supporting one or more of the 4 categories of capabilities outlined below.

### *Safety-Rated Monitored Stop*

A robot that supports Safety-Rated Monitored Stop works in a non-collaborative mode of operation until a person's approach is detected by the perimeter safeguards. Traditional industrial robots typically have the ability to come to an emergency stop when a safeguard is triggered, such as a light curtain or emergency stop button and the robot performs a category 0 or 1 stop which leaves the arm de-energized. A robot that supports the Safety-Rated Monitored Stop capability instead comes to a category 2 stop which allows it to stay energized and continue operation seamlessly after the person exits the safeguarded zone, because they have the ability to ensure the robot won't ever move in this stopped state. The robot must be equipped with a safety-rated soft axis and space limiting function and a safety-rated monitored stop function that meets the functional safety performance level defined in ISO 10218-1. This method of implementing collaborative safety is specific to traditional industrial robots that are dangerous, yet have advanced safety-rated controls capabilities to allow an operator to enter its workspace temporarily. This method is not applicable to Baxter and Sawyer as they do not have a non-collaborative mode and do not have the safety rated mechanisms it describes.

### *Hand Guiding*

Hand Guiding builds upon Safety Rated Monitored Stop. Robots that support this capability come to a category 2 stop when a person enters the safeguarded space, then the person uses an enabling device to activate motion and operate the robot in a safe manner by hand. When training Baxter or Sawyer by demonstration you are not in this definition of had guided collaborative operation since Baxter has no non-collaborative automatic mode and the method by which you train by demonstration does not use an enabling device. This definition of Hand Guided Collaborative robots is intended to encompass robots that are otherwise unsafe to be near but have advanced safety-rated controls that make it safe for the robot to be powered while a person is in within its workspace, and to enable hand guided actions.

### *Speed and Separation Monitoring*

The ultimate method for traditional, dangerous, industrial robots to work around people is to have them adapt in real time to the presence of people. In this mode, the robot has a safety rated method of monitoring the separation between nearby people and the robot, and adjusting its speed to ensure safety. The closer anything or anyone gets to the robot, it is required to reduce speed, and come to a safety rated monitored stop when that person approaches within a minimum separation distance. As you can imagine, creating a self-monitoring, redundant safety system that can calculate the separation distance and relative motion of any and all people within the safeguarded space and the robot is a very big challenge, so there are currently no solutions available that leverage this mode. Some approximate it using a series of light curtains or laser scanners.

While Baxter has a sonar ring that can allow it to detect the presence of objects near the robot, it has no safety function and is not related to this mode of collaborative operation. Currently the sonar ring has no behavioral functions tied to it in the manufacturing version of the robot beyond being a visual indicator that the robot is working and reacting to inputs. It is however being used occasionally in the education and research communities using the Baxter Research Robot for many creative applications.

### *Power and Force Limiting – **Rethink Robotics' robots fit into this category***

This category of robot has limited power and force capabilities either through the use of safety-rated controls or through inherent design. Baxter and Sawyer fit into this category via inherent design. The capabilities of the motor and gearbox combinations at the maximum voltage available have been sized to keep the maximum joint torques very low. The gearbox design is also very efficient, making it easy to overcome the robot's power and push the robot away, back driving the motor and gearbox. Lastly, the series elastic actuator joint design provides a spring at every joint that can also absorb the energy of impact as well as make it easy to push the robot away, eliminating the risk of clamping or trapping.

Other robots in this category use safety rated controls and safeguards to limit the robot's abilities when running in collaborative operation. Some have these constraints active 100% of the time, others engage them when the robot is changed to its collaborative mode. While the safeguards themselves must meet the requirements of ISO 10218 in terms of reliability and redundancy, there are also requirements on controlling access since unauthorized access could result in configuring settings that would be unsafe.

The challenge with Power and Force Limiting is that there a lack of definitive data available to use in deciding what an acceptable force/power/speed/energy should be for the robot during collaborative operation. An annex of the upcoming TS15066 presents a human body model along with data from a University of Mainz pain onset study. In that study, 100 test subjects consisting of people from general society (e.g. the university) as well as some metal working were tested using an apparatus that presses on the target body point with a 1cm2 probe covered with a pressure-sensitive foil grid. In each test of one of the 29 body regions tested, the subject squeezed or released an enabling device when they felt the probe contact switched from pressure to pain. No test subject experienced an injury (i.e. no bruises or lacerations) and when the subjects were asked to rate the resultant pain on a scale of 1-10, the vast majority gave the score as 3 or less.

The table in the annex provides pain onset pressure values from the study for quasi-static contact (clamping) situations. At those pressures, 75% of participants had begun to feel pain, with no injuries - not even a bruise. It also provides force values for quasi-static contact that were derived from a study of all available literature on topics like closing subway doors and blunt force trauma. Ongoing research suggests these values are conservative, however it will likely be several years before more HRI-specific research on injury thresholds can provide more specific data. The table then provides a multiplier for determining an estimate for transient contact. Transient contact is the short duration contact where the human body part can react or be deflected. An injury study around injury onset found that the transient limits could be 2 to 9 times higher than quasi-static limits, so the table conservatively lists a multiplier of 2 to get to the equivalent transient values. Unfortunately getting approvals to determine injury thresholds is difficult, let alone finding test subjects willing to be tested to the point of bruising or lacerations, so this data may be all that industry has available for reference for a long time.

# Performing a Risk Assessment

RIA TR R15.306:2014 provides a detailed methodology for performing risk assessments in general, while specifically for Power and Force Limited collaborative robots, ISO TS 15066 and ANSI R15.06/ISO 10218-2 provide guidance on the right aspects to be evaluating. It is important to evaluate the entire robotic application including not just the robot itself, but all tools, fixtures, parts, end effectors, machinery, etc within the robotic cell. Once all hazards in normal operation, including capturing both intended operation and interaction situations as well as unintended, foreseeable misuse situations, the hazards should be scored on probability of exposure, severity of injury hazard, frequency of exposure, and avoidability.

After determining the hazards and their risks, the standards require users to attempt to eliminate or reduce them to acceptable levels. There is a hierarchy of steps to consider starting with elimination of hazards at the top to the use of personal protective equipment as the last level. After applying any changes to the work cell to eliminate or mitigate the hazards, each hazard risk is re-scored to determine a final risk level and show the work cell meets the desired level of risk.

In the absence of specific limits or standardized, repeatable, precise force/pressure measuring techniques, customers are testing the robot's performance with respect to these hazards and determining the injury severity risk using common sense. In situations where either the part being handled presents a risk or some equipment in the collaborative work cell presents a hazard, some customers are choosing to add protective measures that slow, pause or stop the robot when something is detected within proximity of the robot or the machine it is tending. To date, no customer has required a cage like a traditional industrial robot for a Baxter application.

# Background on Industrial Robot Safety Standards

ISO 10218:2011 is the key international standard for industrial robot safety standards relating to collaborative robots (ISO stands for International Standards Organization). Part 1 covers the robot itself, while Part 2 covers the robot application. In the US, ANSI (American National Standards Institute) has adopted this standard as R15.06:2012. The ISO 10218 standard builds upon two more fundamental standards, ISO 13849 which covers safety of machinery and in particular safety related parts of the control system, and ISO 12100 which discusses general principles for risk assessment and risk reduction for the safe design of machinery.

When the work to update ISO 10218 was completed in 2011, the vision for collaborative robots was uncertain, and the standard could not yet provide enough guidance on how to assess and deploy this new class of robots and applications. Since then, Baxter has come to market, along with other robots that promote themselves as collaborative, and the industry came to realize that more information and guidance is needed for collaborative robot applications. As a result, the ISO, ANSI and other national standards committees began work began on a new ISO Technical Specification called ISO TS 15066. This new document should come out in late 2015/early 2016 and will provide more detailed guidance on how to analyze a collaborative robot application.

The emergence of collaborative robotics has also come on the heels of a general trend in the industry away from defining standards that limit the functionality and usefulness of robots irrespective of the intended use. Instead, the standards require an approach that evaluates the application as a whole. ISO 10218 calls for the integrators/users of robots to perform a risk assessment of the planned application to evaluate all the hazards presented and provides a sound methodology for assessing risks and determining what measures are necessary to ensure the safety of workers. In the United States, ANSI and RIA (Robotic Industries Association) have now released Technical Report TR R15.306:2014 to provide very risk assessment methodology information specifically to help guide users of robotics.