Robotic Glossary of Terms

Acceleration Level: The measure of variation of joint speeds over time. Double and single differentiation of this level gives the overall change in position and change in position overtime, respectively. Refer to position level and velocity level.

Accuracy: A measure of a robot's capability to repeat the same task multiple times without changing the closeness to a certain point. Accuracy is the measurement of the deviation between the command characteristic and the attained characteristic, or the precision with which a computed or calculated robot position can be attained. Accuracy is normally worse than the arm's repeatability. Accuracy is not constant over the workspace, due to the effect of link kinematics.

Active Compliant Robot: An active compliant robot is one in which motion modification during the performance of a task is initiated by the control system. The induced motion modification is slight, but sufficient to facilitate the completion of a desired task.

Actual Position: The position or location of the tool control point. Note that this will not be exactly the same as the demand position due to a multitude of un-sensed errors (such as link deflection, transmission irregularity, tolerances in link lengths, etc.).

Actuator: A power mechanism used to effect motion, or maintain position of the robot, by conversion of different energy types, such as electrical or mechanical processes, using liquid or air (for example, a motor which converts electrical energy to effect motion of the robot). The actuator responds to a signal received from the control system.

Algorithm: A list of steps used to find a solution to a given problem.

Analytical Methods: A mathematical way to solve problems without repetitive attempts to approximate an answer.

Application Program: A sequence of steps that specifies what jobs the robots will perform. The program can be personalized by the owner to fit specific designs.

Arc Welding: A type of welding that uses direct or alternating current to supply power from an electrode to the metal, creating an electrical arc. The place on the metal to be weld is melted. Costs are kept at a minimum, making the process used in a broad range.

Arc Welding Robot: Refers to an automated welding process performed by an industrial robot to create an electric arc between an electrode and a base material to melt the metals at the welding point.

Arm: An interconnected set of links and powered joints comprising a robot manipulator that supports and/or moves a wrist and hand or end-effector through space. The arm itself does not include the end-effector. See Manipulator, End-Effector and Wrist.

Articulated Manipulator: A manipulator with an arm that is broken into sections (links) by one or more joints. Each of the joints represents a degree of freedom in the manipulator system and allows translation and rotary motion.

Articulation: Describes a jointed device, such as a jointed manipulator. The joints provide rotation about a vertical axis, and elevation out of the horizontal plane. This allows a robot to be capable of reaching into confined spaces.

Assembly Robot: A robot designed specifically for mating, fitting, or otherwise assembling various parts or components, in a sequential manner, to create completed products. Primarily used for grasping parts and mating or fitting them together, such as in assembly line production.

Attended Continuous Operation: Robots are observed while carrying out assigned applications at a minimum speed.

Attended Program Verification: A worker in the restricted area checks the robots assigned jobs at the specified speed to ensure proper working conditions.

Automatic Mode/Operation: The state when the robot begins self-moving operations - executes the programmed jobs without worker involvement.

Automation: A system that uses programmable equipment for production. The equipment is capable of being altered and controlled by the program depending on the product.

Automation Solutions: Machinery and programs used for automatic operation.

Autonomous: Procedures in a system occurring without worker involvement and pre-programmed operations.

Awareness Barrier/Signal: A restriction that physically or visually (example: sound or light) informs a human of a danger or hazard being near.

Axis: A direction used to specify the robot motion in a linear or rotary mode. The point that something, such as a tool, rotates around. The number of axes a robot has varies, but the majority of industrial robots are 4-axis or 6-axis.

Axis Acceleration: The maximum acceleration that a particular axis can attain while the robot is loaded with the suggested payload.

Backplane: A circuit board containing sockets into which other circuit boards can be plugged in. In the context of PCs, the term backplane refers to the large circuit board that contains sockets for expansion cards.

Ball Screw: A device for transforming rotary motion to linear, or vice versa, incorporating a threaded rod portion and a nut consisting of a cage holding many ball bearings.

Barrier: A physical structure used to separate people from a restricted area.

Base: The stable platform to which a robotic arm is attached.

Biomimetic: Imitation of biological systems occurring in nature.

Burn-In: A robot testing procedure where all components of the robot are operated continuously for an extended period of time. This is done to test movement and movement programming of the robot, at early stages, to avoid malfunctions after deployment.

Business Process Automation (BPA): Efficiency of the process is improved by introducing enterprise software throughout the entire process while reducing worker involvement.

CAD (Computer-Aided Design): Computer graphic applications designed to allow engineering of objects (or parts), which are to be manufactured. A computer is used as a tool to design schematics and produce blueprints, which enable the accurate production of the object. The CAD system enables the three-dimensional drawings of basic figures, exact sizing and placement of components, making lines of specified length, width, or angle, as well as satisfying varying geometric shapes. This system also allows the designer to test a simulated part under different stresses, loads, etc.

CAM (Computer-Aided Manufacturing): Computer software is used to design and/or alter the manufacturing process.

Cam: The centerline of rotation of a part that is not at the geometric center, making other parts push on it, causing the part to move in and out.

Carousel: A rotating platform that delivers objects to a robot, and serves as an object queuing system. This carousel delivers the objects, or work-pieces to the loading/unloading station of the robot.

Cartesian-Coordinate Robot: A Cartesian-Coordinate robot is a robot whose manipulator-arm degrees of freedom are defined by Cartesian coordinates. This describes motions that are east-west, north-south and up-down, as well as rotary motions to change orientation.

Cartesian Manipulator: A robot arm with prismatic joints, which allows movement along one or more of the three- axes in the X, Y and Z coordinate system.

Cartesian Robot: The axes of the three prismatic or linear motion joints of the robot are in the same direction of a Cartesian coordinator.

Cartesian Topology: A topology, which uses prismatic joints throughout, normally arranged to be perpendicular to each other.

Central Processing Unit (CPU): The main circuit board and processor of the Controller System.

Centrifugal Force: When a body rotates about an axis other than one at its center of mass, it exerts an outward radial force called centrifugal force upon the axis, which restrains it from moving in a straight tangential line. To offset this force, the robot must exert an opposing torque at the joint of rotation.

Chassis: The parts making up a machine, not including the body or casing. In the case of an automobile, this would include parts such as the frame and engine, but not the body surrounding these parts.

Circular Motion Type: A calculated path that the robot executes, and is circular in shape.

Clamp: An end-effector which serves as a pneumatic hand that controls the grasping and releasing of an object. Tactile and feed-back force sensors are used to manage the applied force to the object by the clamp. See End-Effector.

Closed-Form: Iteration or repeated approximation to find a solution for this problem formulation.

Closed-Loop: Control achieved by a robot manipulator by means of feed-back information. As a manipulator is in action, its sensors continually feed-back information to the robot's controller, which are used to further guide the manipulator within the given task. Many sensors are used to feed-back information about the manipulator's placement, speed, torque, applied forces, as well as the placement of a targeted moving object, etc. See Feedback.

Collision Sensor: A sensor that detects and informs the controller to stop the robot prior to or during a crash. Other terms for this device include crash protection device, robot safety joint, and robotic clutch, among others.

Command Interpreter: A module or set of modules that determines what the received command means. The command is broken down into parts (parsed) and processed.

Command Position: The endpoint position of a robot motion that the controller is trying to achieve,

Compensator: A remote device that involves multiple shear pads to help peg-in-hole operations. The shear pads are elastomers, also known as polymers. The device uses three to twelve of these shear pads.

Compliance: Displacement of a manipulator in response to a force or torque. A high compliance means the manipulator moves a good bit when it is stressed. This is called spongy or springy. Low compliance would be a stiff system when stressed.

Compliant Robot: A robot that performs tasks, with respect to external forces, by modifying its motions in a manner that minimizes those forces. The indicated or allowed motion is accomplished through lateral (horizontal), axial (vertical) or rotational compliance.

Computer-Aided Design (CAD): Computer graphic applications designed to allow engineering of objects (or parts), which are to be manufactured. A computer is used as a tool to design schematics and

produce blueprints, which enable the accurate production of the object. The CAD system enables the three-dimensional drawings of basic figures, exact sizing and placement of components, making lines of specified length, width, or angle, as well as satisfying varying geometric shapes. This system also allows the designer to test a simulated part under different stresses, loads, etc.

Computer-Aided Manufacturing (CAM): Computer software is used to design and/or alter the manufacturing process.

Configuration: The arrangement of links created by a particular set of joint positions on the robot. Note that there may be several configurations resulting in the same endpoint position.

Conservative Motion: The end-effector and joints always move in their specific route.

Contact Sensor: A device that detects the presence of an object or measures the amount of applied force or torque applied on the object through physical contact with it. Contact sensing can be used to determine location, identity, and orientation of work-pieces.

Continuous Path: Describes the process where by a robot is controlled over the entire path traversed, as opposed to a point-to-point method of traversal. This is used when the trajectory of the end-effector is most important to provide a smooth movement, such as in spray painting etc. See Point-to-Point.

Control Algorithm: A monitor used to detect trajectory deviations in which sensors detect such deviations and torque applications are computed for the actuators.

Control Command: An instruction fed to the robot by means of the human-to-machine input device. See Pendant (Teaching). This command is received by the robot's controller system and is interpreted. Then, the proper instruction is fed to the robot's actuators, which enable it to react to the initial command. Many times the command must be interpreted with the use of logic units and specific algorithms. See Input Device and Instruction Cycle.

Control Device: Any piece of control hardware providing a means for human intervention in the control of a robot or robot system, such as an emergency-stop button, a start button, or a selector switch.

Control Mode: The means by which instructions are communicated to the robot.

Control Program: The control information built into the robot or automated system that allows for possible behaviors. The control information is not expecteded to be altered.

Controllability: The property of a system by which an input signal can take the system from an initial state to a desired state along a predictable path within a predetermined period of time.

Controller: An information processing device whose inputs are both the desired and measured position, velocity or other pertinent variables in a process and whose outputs are drive signals to a controlling motor or actuator. Controller System: The robot control mechanism is usually a computer of some type, which is

used to store data (both robot and work environment), and store and execute programs, which operate the robot. The controller system contains the programs, data, algorithms; logic analysis, and various other processing activities, which enable it to perform. See Robot.

Coordinated Straight Line Motion: The Tool Center Point follows a specific path allowing the axes of the robot to come to their specified end points at the same time. This allows for a smooth operation of movement.

CPU (Central Processing Unit): The main circuit board and processor of the Controller System.

Cycle: A single execution of a complete set of moves and functions contained within a robot program.

Cyclic Coordinate System: A coordinate system that defines the position of any point in terms of an angular dimension, a radial dimension, and a height from a reference plane. These three dimensions specify a point on a cylinder.

Cyclo Drive: A brand name for a speed reduction device that converts high speed low torque to low speed high torque, usually used on the major axis (larger).

Cylindrical Robot: The axes of the robot correspond to a cylindrical coordinate system.

Cylindrical Topology: A topology where the arm follows a radius of a horizontal circle, with a prismatic joint to raise or lower the circle. Not popular in industry.

Dead Man Switch: See **Enabling Device**.

Degrees of Freedom: The number of independent directions or joints of the robot, which would allow the robot to move its end effector through the required sequence of motions. A robotic joint is equal to one degree of freedom. For arbitrary positioning, 6 degrees of freedom are needed: 3 for position (left-right, forward-backward, and up- down) and 3 for orientation (yaw, pitch and roll).

Device: Hardware used to control various parts of a system.

Dexterity: The measure of the robot's skill of completing specific difficult paths.

Digital Computer: The system of binary numbers is most commonly used as digits for calculations or operations by the computer.

Direct-Drive: Joint actuation including no transmission elements, i.e. the link is bolted onto the output of the motor.

Direct Numerical Control (DNC): Equipment that is controlled numerically receives data inputs from a computer.

Direct Search: Trial solutions are used to search for a numerical answer as opposed to carefully solving the derivatives.

Downtime: A period of time in which a robot, or production line is shut down due to malfunction or failure. See Uptime.

Drive: A speed (gear) reducer to convert high-speed low torque to low speed high torque. See Harmonic Drive, Cyclo Drive, Rotary Vector Drive.

Drive Power: Actuators convert this source of energy into usable energy for the robot's movement.

Drop Delivery: A method of introducing an object to the workplace by gravity. Usually, a chute or container is so placed that, when work on the part is finished, it will fall or drop into a chute or onto a conveyor with little or no transport by the robot.

Dynamic Model: This model shows the forces causing the robot's movement.

Dynamics: The study of motion, the forces that cause the motion, and the forces due to motion. The dynamics of a robot arm are very complicated as they result from the kinematical behavior of all masses within the arm's structure. The robot arm kinematics is complicated in themselves.

Emergency Stop (ESTOP): Immediately stops motion and tasks of the system. This is done by the operation of a circuit, using hardware-based components, that overrides all other robot controls, removing drive power from the robot actuators that causes all moving parts to stop.

Enabling Device: A manually operated device, which when continuously activated, permits motion. Releasing the device shall stop robot motion and motion of associated equipment that may present a hazard.

Encoder: A feedback device in the robot manipulator arm that provides current position (and orientation of the arm) data to the controller. A beam of light passes through a rotating code disk that contains a precise pattern of opaque and transparent segments on its surface. Light that is transmitted through the disk strikes photo-detectors, which convert the light pattern to electrical signals. See Feedback, Closed-Loop Control and Feedback Sensor.

End-Effector: An accessory device or tool specifically designed for attachment to the robot wrist or tool mounting plate to enable the robot to perform its intended task. (Examples may include gripper, spot weld gun, arc weld gun, spray point gun, or any other application tools.)

End-Effector Space: The area of the robot's end-effector movement with respect to its base.

End-Of-Arm Tooling (EOAT): Application tools that are located at the end of the robot arm. The quality of the EOAT greatly affects the performance of the system.

Endpoint: The nominal commanded position that a manipulator will attempt to achieve at the end of a path of motion. The end of the distal link.

Energy Source: Energy is provided by conversion of various types of sources such as chemical, thermal, mechanical etc.

Equality Constraint: The end-effector's change of position, movement and location must be equal to a certain number.

Error: The difference between the actual response of a robot and a command issued.

Error Function: A number is chosen to stand for a discrepancy in the actual value and the desired value for a dependent variable.

E-STOP (Emergency Stop): Immediately stops motion and tasks of the system. This is done by the operation of a circuit, using hardware-based components, that overrides all other robot controls, removing drive power from the robot actuators that causes all moving parts to stop.

Expandability: Being able to add resources to the system, such as memory, larger hard drive, new I/O card, etc.

Exponential Assembly: Nanorobots replicate themselves repeatedly.

Factory Automation: The process of integrating industrial machinery with the help of control software. This integration increases efficiency, productivity and quality while decreasing costs.

Feedback: A signal from the robot equipment about conditions, as they actually exist, rather than as the computer has directed them to exist. See Feedback Control and Feedback Sensor.

Feedback Control: A type of system control obtained when information from a manipulator or sensor is returned to the robot controller in order to obtain a desired robot effect. See Feedback, Closed-Loop Control and Feedback Sensor.

Feedback Sensor: A mechanism through which information from sensing devices is fed back to the robot's control unit. The information is utilized in the subsequent direction of the robot's motion. See Closed-Loop Control and Feedback Control.

Fixed/Hard Automation: Automated, electronically controlled system for simple, straight or circular. These systems are mainly used for large production runs where little flexibility is required.

Flexibility: The diverse jobs that a robot is capable of executing.

Flexible Automation: The ability for a robot and system to be reconfigured and change product design easily. Productivity is increased due to minimized setup times.

Force Feedback: A sensing technique using electrical signals to control a robot end-effector during the task of the end-effector. Information is fed from the force sensors of the end-effector to the robot control unit during the particular task to enable enhanced operation of the end-effector. See Feedback, Feedback Sensor and Force Sensor.

Force Sensor: A sensor capable of measuring the forces and torque exerted by a robot and its wrist. Such sensors usually contain strain gauges. The sensor provides information needed for force feedback. See Force Feedback, Strain, Stress, and Strain Gauge.

Forward Kinematic Solution: The calculation of mathematical algorithms, along with joint sensors, used to find the endpoint position given the joint positions. For most robot topologies this is easier than finding the inverse kinematic solution.

Frame: A coordinate system used to determine a position and orientation of an object in space, as well as the robot's position within its model.

Fully Constrained Robot: The number of equality constraints on the robot is equal to the number of independent joints.

Gantry: An adjustable hoisting machine that slides along a fixed platform or track, either raised or at ground level along the X, Y and Z axis.

Gantry Robot: A robot which has three degrees of freedom along the X, Y and Z coordinate system. Usually consists of a spooling system (used as a crane), which when reeled or unreeled, provides the up and down motion along the Z axis. The spool can slide from left to right along a shaft which provides movement along the Z axis. The spool and shaft can move forward and back along tracks which provide movement along the Y axis. Usually used to position its end-effector over a desired object and pick it up.

Gravity Loading: The force exerted downward, due to the weight of the robot arm and/or the load at the end of the arm. The force creates an error with respect to position accuracy of the end-effector. A compensating force can be computed and applied bringing the arm back to the desired position.

Gripper: An end effector that is designed for seizing and holding, and "grips" or grabs an object. It is attached to the last link of the arm. It may hold an object using several different methods, such as: applying pressure between its "fingers", or may use magnetization or vacuum to hold the object, etc. See End-Effector.

Hand: A clamp or gripper used as an end-effector to grasp objects. See End Effector, Gripper.

Harmonic Drive: Compact lightweight speed reducer that converts high-speed low torque to low speed high torque. Usually found on the minor axis (smaller).

Harness: Usually several wires, bundled together to deliver power and/or signal communications to/from devices. For example, the robot motors are connected to the controller through a wire harness.

Hazard: A possible dangerous or harmful situation.

Hazardous Motion: Unintended/unexpected robot motion that may cause injury.

Hold: A stopping of all movements of a robot during its sequence, in which some power is maintained on the robot. For example, program execution stops; however, power to the servo motors remain on if restarting is desired.

Home Position: A known and fixed location on the basic coordinate axis of the manipulator where it comes to rest, or to an indicated zero position for each axis. This position is unique for each model of manipulator.

Human-Computer Interaction (HCI): Analysis of the relationship of computers and humans.

Hybrid: The robot has a combination of pick and place and servo controlled parts.

Inductive Sensors: The class of proximity sensors, which has half of a ferrite core, whose coil is part of an oscillator circuit. When a metallic object enters this field, at some point the object will absorb enough energy from the field to cause the oscillator to stop oscillating. This signifies that an object is present in a given proximity. See Proximity Sensor.

Industrial Automation: Also referred to as automation, uses numerical control during the use of control systems (e.g. computers) to control industrial machinery and processes, replacing human operators. It is a step beyond mechanization, where human operators are provided with machinery to assist them with the physical requirements of work. The most visible part of modern automation can be said to be industrial robotics. Some advantages are repeatability, tighter quality control, waste reduction, and integration with business systems, increased productivity and reduction of labor.

Industrial Equipment: Machinery capable of executing industrial operations.

Industrial Robot: A re-programmable multifunctional manipulator designed to move material, parts, tools, or specialized devices, through variable programmed motions for the performance of a variety of tasks. The principle components are: one or more arms that can move in several directions; a manipulator, a computer controller that gives detailed movement instructions.

Industrial Robot System: A system of robots, machinery, and devices that are programmed to perform operations while incorporating an interface.

Industrial Robotics: The idea of incorporation of a robot system for production.

Inequality Constraint: A limitation of a feature that may vary such as joint movement, speed, and torque.

Input Devices: A variety of devices, which allow a human to machine interface. This allows the human to program, control, and simulate the robot. Such devices include programming pendant, computer keyboards, a mouse, joysticks, push buttons, operator panel, operator pedestal, etc.

Instruction: A line of programming code that causes action from the System Controller. See Command.

Instruction Cycle: The time it takes for a robot controller system's cycle to decode a command or instruction before it is executed. The Instruction Cycle must be analyzed very closely by robotic programmers to enable speedy and proper reaction to varying commands.

Integrate: To fit together different subsystems, such as robots and other automation devices, or at least different versions of subsystems in the same control shell.

Integrator: A company that combines and coordinates separate parts or elements into a unified whole using mechanical means.

Intelligent Robot: A robot that can be programmed to make performance choices contingent on sensory inputs with little or no help from human intervention. See Robot.

Interface: The separation between robots and the equipment not nearby. The sensors that are required for communication between the devices use signals relaying input and output data.

Interlock: The control of a device starting or stopping is dependent upon the action of another device.

Internal Sensor: An apparatus within the manipulator arm that sends information on motion to a control unit.

Interpolation: The method by which endpoint paths are created. In general to specify a motion a few knot points are defined and then all the intermediate positions between them are calculated by mathematical interpolation. The interpolation algorithm used therefore has a dramatic effect of the quality of motion.

Inverse Kinematics: Determination of a joint's overall change in position based on restrictions on the end-effector's motion of a robot.

Iteration: A method of solving a problem by repeating the same procedure to find a more exact solution.

Jacobian: End-effector velocity is related to joint speeds by this matrix of first-order partial derivatives.

Jacobian Matrix: The Jacobian matrix relates the rates of change of joint values with the rates of change of endpoint co-ordinates. Essentially it is a set of algorithm calculations that are processed to control the positioning of a robot.

Joint: A part of the manipulator system, which allows a rotation and/or translational degree of freedom of a link of end-effector - the parts of the robot arm which actually bend or move.

Joint-Interpolated Motion: A method of coordinating the movement of the joints, such that all joints arrive at the desired location simultaneously. This method of servo control produces a predictable path regardless of speed and results in the fastest pick and place cycle time for a particular move. See Pick and Place Cycle, Servo-system.

Joint Motion Type: Also known as Point-to-Point motion, is a method of path interpolation that commands the movement of the robot by moving each joint directly to the commanded position so that all axis arrive to the position at the same time. The path is predictable, however the path will not be linear.

Joint Space: The area and coordinate system the joints of the robot consume.

Jointed Arm Robot: The arm of the robot has two junctions allowing for rotation and enhanced movement much like a person's shoulder and elbow on their arm.

Kinematic Influence Coefficients: The number of input joints affects movement of the robot and the response of the system due to the effect on complex and coupled nonlinear differential equations.

Kinematics: Analysis of motion by leaving out information of forces. The relationship between the motion of the endpoint of a robot and the motion of the joints. For a Cartesian robot this is a set of simple linear functions (linear tracks that may be arranged in X, Y, Z directions), for a revolute topology (joints that rotate) however, the kinematics are much more complicated involving complicated combinations of trigonometry functions. The kinematics of an arm is normally split into forward and inverse solutions.

Ladle Gripper: An end-effector, which acts as a scoop. It is commonly used to scoop up liquids, transfer it to a mold and pour the liquid into the mold. Common for handling molten metal under hazardous conditions. See End-Effector.

LaGrange Multipliers: Use allows for an unconstrained problem with performance criteria as opposed to a constrained problem with equality constraints.

Laser: Acronym for Light Amplification by Stimulated Emission of Radiation. A device that produces a coherent monochromatic beam of light which is extremely narrow and focused but still within the visible light spectrum. This is commonly used as a non-contact sensor for robots. Robotic applications include: distance finding, identifying accurate locations, surface mapping, bar code scanning, cutting, welding, etc.

Limiting Device: A separate apparatus that places a restriction on the maximum envelope. This restriction occurs by terminating motion of the robot.

Linear Motion Type: Is a method of path interpolation that commands the movement of the robot by moving each joint in a coordinated motion so that all axis arrive to the position at the same time. The path of the tool control point (TCP) is predictable and will be linear.

Linearly Dependent: Numbers or functions related by addition, subtraction or multiplying by a scalar.

Link: A rigid part of a manipulator, which connects adjacent joints. (In a human body, the links are the bones.)

Load Cycle Time: A manufacturing or assembly line process term, which describes the complete time to unload the last work-piece and load the next one.

Magnetic Detectors: Robot sensors that can sense the presence of ferromagnetic material. Solid-state detectors with appropriate amplification and processing can locate a metal object to a high degree of precision. See Sensor.

Maintenance: Ensuring that robots and manufacturing systems are working properly and repairing any problems observed.

Manipulator: The arm of a robot. A machine or robotic mechanism which usually consists of a series of segments jointed or sliding relative to one another, for the purpose of grasping and/or moving objects (pieces or tools) usually in several degrees of freedom. The control of the manipulator may be by an operator, a programmable electronic controller, or any logic system (for example cam device, wired, etc.) See Arm, Wrist, and End-Effector, Master-Slave Manipulator.

Manual Programming: The user physically sets specific tasks and limits on the robot.

Manufacturing Robot: A mechanical device that uses automation to transform raw materials into finished goods for sale.

Material Handling: The process by which a robotic arm transfers materials from one place to another.

Material Processing Robot: A robot designed and programmed so that it can machine, cut, form, or change the shape, function or properties of materials it handles between the time the materials are first grasped and the time they are released in a manufacturing process.

Maximum Envelope Space: The largest area that all parts of the robot cover with its various movements.

Mechanical: Use of machines and apparatuses.

Mechanization: Integration of machinery and equipment into manufacturing processes.

Mobile Robot: A type of robot with its own engine or power able to move without constraints on its path.

Modularity: The property of flexibility built into a robot and control system by assembling separate units, which can be easily joined to or arranged with other parts or units.

Moment: The measure of rotation about a reference object when a force is applied. When a reference point is used, the moment is the cross product of the amount of force and the perpendicular distance between the point and the line of force. When a reference line is used, the moment is the cross product of amount of force and the shortest distance between the line and the point where the force is applied. When a reference plane is used, the moment is the cross product of the amount of force and the perpendicular distance from the plane to the point where the force is applied.

Motion Axis: The line defining the axis of motion, either linear or rotary, of a segment of a manipulator.

Motor: See **Servo Motor**.

Muting: Turning off the presence-sensing safeguarding device during a part of robot operation.

Nanotechnology: (Molecular Manufacturing) The science of studying and inventing products on the small scale of the molecular level.

Normalize: The process of relating factors into similar magnitudes by scaling.

Numerical Methods: Analytical procedures or heuristics repeatedly used by a computer to find a solution.

Off-Line Programming: A way to store procedure information for a robot on a computer to be used in the future. A programming method where the task program is defined on devices or computers separate from the robot for later input of programming information to the robot.

On-Line Programming: A means of programming a robot while the robot is functioning. This becomes important in manufacturing and assembly line production due to keeping productivity high while the robot is being programmed for other tasks.

Operating Envelope Space: The part of the restricted envelope taken up during the specified robots movements.

Operator: The person designated to start, monitor and stop the intended productive operation of a robot or robot system. An operator may also interface with a robot for productive purposes.

Optical Encoder: A detection sensor, which measures linear or rotary motion by detecting the movement of markings past a fixed beam of light. This can be used to count revolutions, identify parts, etc.

Optical Proximity Sensors: Robot sensors which measures visible or invisible light reflected from an object to determine distance. Lasers are used for greater accuracy.

Optimization: Process of finding the best values for the independent variables within a function, which is most commonly the maximum or minimum value.

Orientation: The angle formed by the major axis of an object relative to a reference axis. It must be defined relative to a three-dimensional coordinate system. Angular position of an object with respect to the robot's reference system. See Roll, Pitch and Yaw.

Palletizing: Used to move parts onto a pallet to be transported.

Parallel Robot: The linear or rotation joints of the robot's arms match each other in position and direction.

Path: The continuous focus of positions (or points in three dimensional space) traversed by the tool center point and described in a specified coordinate system.

Payload – Maximum: The maximum mass that the robot can manipulate at a specified speed, acceleration/deceleration, center of gravity location (offset), and repeatability under continuous operation over a specified working space. Maximum payload is specified in kilograms.

Pendant [Teach Pendant]: A hand-held input device linked to the control system with which a robot can be programmed or moved. This enables the human operator to stand in the most favorable position to observe, control, and record the desired movements in the robot's memory.

Pendant Teaching: The mapping and recording of the position and orientation of a robot and/or manipulator system as the robot is manually moved in increments from an initial state along a path to a final goal state. The position and orientation of each critical point (joints, robot base, etc.) is recorded and stored in a database for each taught position the robot passes through on its path toward its final goal. The robot may now repeat the path on its own by following the path stored in the database.

Performance Criteria: Evaluation of the robot's operations determined by kinematic and dynamic models.

Pick and Place Cycle: The amount of time it takes for a manipulator to pick up an object and place it in a desired location, then return to its rest position. This includes time during the acceleration and deceleration phases of a particular task. The robots movement is controlled from one point location in space to another in a point-to-point (PTP) motion system. Each point is programmed into the robot's control memory and then played back during the work cycle.

Pick and Place Robot: A type of robot that moves parts from one place to another.

Pick and Place Task: A repetitive part transfer task composed of a picking action followed by a placing action.

Pitch: Rotation of the end-effector in a vertical plane around the end of the robot manipulator arm. See Roll and Yaw.

Plant Description: Information on the motion and forces of the robot.

Point-To-Point (PTP): Manipulator motion in which a limited number of points along a projected path of motion is specified. The manipulator moves from point to point rather than a continuous smooth path.

Pose: Alternative term for robot configuration, and describes the linear and angular position. The linear position includes the azimuth, elevation, and range of the object. The angular position includes the roll, pitch, and yaw of the object. See Roll, Pitch, and Yaw.

Position: The definition of an object's location in 3-D space, usually defined by a 3-D coordinate system using X, Y and Z coordinates.

Position Level: The measure of the overall change in location of a joint. This can also be found by the double integration of acceleration-level and single integration of velocity-level. Refer to acceleration-level and velocity-level.

Positional Assembly: Molecular scale production through the use of component automation.

Presence-Sensing Safeguarding Device: A device designed, constructed, and installed to create a sensing field to detect an intrusion into such field by people, robots, or objects. See Sensor.

Productivity: A measure of the amount of manufactured product compared to the amount of input material.

Program: Noun: A set of tasks to be performed by a robot controller or computer in order to control a system. Verb: To code a computer with a set of procedures or to provide information and tasks for a system to perform.

Programmable Logical Controller (PLC): A solid-state control system, which has a user programmable memory for storage of instructions to implement specific functions such as: I/O control logic, timing, counting arithmetic, and data manipulation. A PLC consists of a central processor, input/output interface, memory, and programming device, which typically use relay equivalent symbols. The PLC is purposely designed as an industrial control system, which may perform functions equivalent to a relay panel or a wired solid-state logic control system, and may be integrated into the robot control system. With this device, the user has more control as it can provide the status of performance of the robots.

Programmable Robot: A feature that allows a robot to be instructed to perform a sequence of steps and then to perform this sequence in a repetitive manner. It can then be reprogrammed to perform a different sequence of steps if desired.

Proximity Sensor: A non-contact sensing device used to sense when objects are a short distance away, and determine the distance of the object. Several types include: radio frequency, magnetic bridge, ultrasonic, and photoelectric. Commonly used for: high speed counting, sensing metal objects, level control, reading coding marks, and limit switches. See Inductive Sensor.

Pseudoinverse: The inversion of a non square matrix used with joint speeds to minimize the magnitude of a vector.

Quality Assurance (QA): Describes the methods, policies, and procedures necessary to conduct quality assurance testing during design, manufacturing and deliver phases of creating, reprogramming, or maintaining robots.

Reach: The distance from the center of the robot to the fullest extension of the robotic arm. The work envelope is determined from this distance.

Real-Time System: A computer system in which the computer is required to perform its tasks within the time restraints of some process simultaneously with the system it is assisting. The computer processes system data (input) from the sensors for the purpose of monitoring and computing system control parameters (outputs) required for the correct operation of a system or process. The computer is required to do its work fast enough to keep pace with an operator interacting with it through a terminal device (such as a screen or keyboard). The operator interacting with the computer has access, retrieval, and storage capability through a database management system. System access allows the operator to intervene and alter the system's operation.

Rebuild: Improvements are made to parts of the robots to return it to its original appearance, performance and life expectancy as closely as possible.

Record-Playback Robot: A manipulator for which the critical points along desired trajectories are stored in sequence by recording the actual values of the joint-position encoders of the robot as it is moved under operational control. To perform the task, these points are played back to the robot's Servo-system. See Servo-System.

Rectangular-Coordinate Robot: A robot whose manipulator arm moves in linear motions along a set of Cartesian or rectangular axis in X, Y and Z directions. The shape of the work envelope forms a rectangular figure. See Work Envelope.

Redundancy: The number of independent variables is more than the number of constraints.

Reliability: The probability or percentage of time that a device will function without failure over a specified time period or amount of usage. Also called the robot's uptime or the Mean Time Between Failure (MTBF).

Remanufacture: To improve and advance robots in order to meet current standards. To upgrade or modify robots to the revised specifications of the manufacturer.

Remote Compliance Center (RCC): Used to decouple linear and rotational motion. All compliance structures have a center though the remote compliance center that is projected outward.

Repair: To renew a robotic system by fixing any problems that have occurred to ensure proper operation.

Repeatability: A measure of how close an arm can repeatedly obtain a taught position. For instance: once a manipulator is manually placed in a particular location and this location is resolved by the robot, the repeatability specifies how accurately the manipulator can return to that exact location. The degree of resolution within the robot control system determines the repeatability. In general an arm's repeatability can never be better than its resolution. See Teach, and Accuracy.

Resolution: The amount of robot joint motion required for the position sensing to change by 1 count. Although the resolution of each joint feedback sensor is normally constant, the resolution of the endpoint in world coordinates is not constant for revolute arms, due to the non-linearity of the arm's kinematics.

Resolved-Rate: Determining the joint's overall changed in velocity over time based on restrictions of the end-effector's motion.

Restricted Envelope Space: A part of the maximum envelope in which the distance determines the boundaries the robot moves after the limiting device is activated.

Revolute Joint: The joints of a robot, which are capable of rotary motion.

Robot: A re-programmable, multifunctional manipulator designed to move material, parts, tools, or specified devices through variable programmed motions for the performance of a variety of tasks. Common elements which make up a robot are: controller, manipulator, and end-effector. See Manipulator, Controller, and End-Effector.

Robot Manufacturer: Creates, builds and/or sells robots and robotic equipment.

Robot Programming Language: An interface between a human user and a robot, which relates human commands to the robot.

Robot Simulation: A method for emulating and predicting the behavior and the operation of a robotic system based on the model (e.g. computer graphics) of the physical system.

Robot System Integrator: A business that merges robots, peripherals, and manufacturing machinery into a production system that functions as a single unit to perform manufacturing tasks.

Robotic Deburring Tool: A tool used to remove material such as burrs, sharp edges, or fins off metal parts.

Robotic Rotary Joint: (Robotic Rotary Union, Robot Slip Ring) Consisting of a stationary part connected to the arm of the robot and a rotating part connected to the wrist and tool allowing for electrical and pneumatic cables to stay in place while cables required for the tool are free to rotate. Electricity is provided by the use of a slip ring.

Robotic Self-Motion: The robot maintains the position of the end-effector while allowing other parts on the robot to move.

Robotic Tool Changer: Component with two mating parts (master and tool) that have been designed to lock together automatically (normally using pneumatic pressure) and are able to pass utilities (e.g. electrical signals, pneumatic supply, water, etc.). The master side of the tool changer mounts to a robot, or other structure. The tool side of the tool changer mounts to tooling, such as grippers, welders, or deburring tools. A robotic tool changer is also known as an automatic tool changer, robot tool changer, robot coupler, robotic coupler, and robotic connector.

ROI (Return on Investment): A measure of performance used to evaluate the efficiency of an investment. The benefit or return of an investment is divided by the cost of the investment resulting in ROI expressed as a percentage or a ratio.

Roll: Rotation of the robot end-effector in a plane perpendicular to the end of the manipulator arm. See Pitch and Yaw.

Rotary Joint: A joint which twists, swings or bends about an axis.

Rotary Vector Drive (RV): A brand name for a speed reduction device that converts high speed low torque to low speed high torque, usually used on the major axis (larger). See Cyclo Drive, Harmonic Drive.

Rotational Motion: Describes circular movement with respect to the axis.

Safeguard: A barrier guard, device or safety procedure designed for the protection of personnel.

Safety Procedure: A set of instructions to help avoid harmful or dangerous situations.

Scale: Changing magnitude by linear operation, i.e. multiplying by a scalar.

SCARA Robot: A cylindrical robot consisting of two parallel rotary joints (horizontally articulated) and provides compliance in one selected plane. Note: SCARA derives from Selectively Compliant Arm for Robotic Assembly.

Self-Assembly: A branch of nanotechnology in which objects, devices, and systems form structures without external prodding.

Self-Replication: Systems and devices in nanotechnology that make copies of themselves on their own.

Sensor: Instruments used as input devices for robots, which enable it to determine aspects regarding the robot's environment, as well as the robot's own positioning. Sensors respond to physical stimuli (such as heat, light, sound, pressure, magnetism, motion) and transmit the resulting signal or data for providing a measurement, operating a control, or both.

Sensory Feedback: Variable data measured by sensors and relayed to the controller in a closed-loop system. If the controller receives feedback that lies outside an acceptable range, then an error has occurred. The controller sends an error signal to the robot. The robot makes the necessary adjustments in accordance with the error signal.

Serial Robot: A type of robot that consists of one series of joints united with links.

Service: To improve, restore, and keep at proper working standards.

Servo Control: The process by which the control system of the robot checks if the attained pose of the robot corresponds to the pose specified by the motion planning with required performance and safety criteria.

Servo-Controlled Robot: The control of a robot through the use of a closed-loop servo system, in which the position of the robot axis is measured by feedback devices and is stored in the controller's memory. See Closed-Loop System, and Servo System.

Servo Motor: An electrical power mechanism used to affect motion, or maintains position of the robot (for example, a motor which converts electrical energy to effect motion of the robot). The motor responds to a signal received from the control system and often incorporates an encoder to provide feedback to the control loop.

Servo Pack: An alternating current electrical power mechanism that is controlled through logic to convert electrical supply power that is in a sine wave form to a Pulse Width Modulated (PWM) square form, delivered to the motors for motor control: speed; direction; acceleration; deceleration; and braking control.

Servo-System: A system in which the controller issues commands to the motors, the motors drive the arm, and an encoder sensor measures the motor rotary motions and signals the amount of the motion back to the controller. This process is continued many times per second until the arm is repositioned to the point requested. See Servo-controlled Robot.

Shoulder: The joint of the robot's manipulator arm connected to the base.

Simulation: A graphical computer program that represents the robot and its environment, which emulates the robot's behavior during a simulated run of the robot. This is used to determine a robot's behavior in certain situations, before actually commanding the robot to perform such tasks. Simulation items to consider are: the 3-D modeling of the environment, kinematics emulation, path-planning emulation, and simulation of sensors. See Sensor, Forward Kinematics, and Robot.

Single Point of Control: Operations of the robot are controlled solely by one source.

Singularity: A configuration where two joints of the robot arm become co-axial (aligned along a common axis). In a singular configuration, smooth path following is normally impossible and the robot may lose control. The term originates from the behavior of the Jacobian matrix, which becomes singular (i.e. has no inverse) in these configurations.

Slow Speed Control: The robot's velocity of movement is decreased enough that the user can remove material or stop motion completely.

Software: A written program used by the computer to instruct the hardware to perform certain tasks.

Solenoid: A coil containing a moveable iron core. The core moves as the electrical current moves through the coil.

Spherical Robot: Consisting of three joints allowing for movement among a polar coordinate system.

Spline: A smooth, continuous function used to approximate a set of functions that are uniquely defined on a set of sub-intervals. The approximating function and the set of functions being approximated intersect at a sufficient number of points to insure a high degree of accuracy in the approximation. The purpose for the smooth function is to allow a robot manipulator to complete a task without jerky motion.

Spline Motion Type: A calculated path that the robot executes, and may be parabolic in shape. A Spline motion may also accomplish a free form curve with mixtures of circular and parabolic shapes.

Start-Up: Providing power to a robot or system to begin operations.

Statics: Analysis of forces without motion.

Swing: A robot's rotational movement with respect to its centerline.

Systems Integrator: A company or person, which has the ability and knowledge to integrate the various parts of a robot welding system. System integrators are used to establish the requirements of a welding application and integrate the required equipment accordingly.

Teach: To program a manipulator arm by manually guiding it through a series of motions and recording the position in the robot controller memory for playback.

Teach Mode: The control state that allows the generation and storage of positional data points affected by moving the robot arm through a path of intended motions.

Teach Pendant: A handheld control box, which is used by an operator to remotely guide a robot through the motions of its tasks. The motions are recorded by the robot control system for future playback. See Accuracy, Pendant Control, Playback Accuracy, Repeatability, and Teach.

Test Automation: Software used to perform tests to observe various information about a system.

Through-Beam: An object detection system used within a robot's imaging sensor system. A finely focused beam of light is mounted at one end and a detector at the other. When the beam of light is broken, an object is sensed.

Tool: A term used loosely to define a working apparatus mounted to the end of the robot arm, such as a hand, gripper, welding torch, screw driver, etc. See Arm, Gripper, and End-Effector.

Tool Center Point (TCP): The central axis of the tool movement.

Tool Frame: A coordinate system attached to the end-effector of a robot (relative to the base frame).

Touch Sensor: Sensing device, sometimes used with the robot's hand or gripper, which senses physical contact with an object, thus giving the robot an artificial sense of touch. The sensors respond to contact forces that arise between themselves and solid objects.

Trajectory Generation (Calculation): The computation of motion functions that allow the movement of joints in a smooth controlled manner.

Transducer: A device that converts energy from one form to another. Generally, a device that converts an input signal into an output signal of a different form. It can also be thought of as a device which converts static signals detected in the environment (such as pressure) into an electrical signal that is sent to a robot's control system.

Trigger Point: The moment a component moves to a different state.

Turnkey Project: A project in which a separate entity is responsible for setting up a plant or equipment and putting it into operation.

Two-Norm: The length of the vector which is found by summing the squares of the lengths then taking the square root of that number.

Uptime: A period of time in which a robot, or production line is operating or available to operate, as opposed to downtime. See Downtime.

Vacuum Cup Hand: An end-effector for a robot arm which is used to grasp light to moderate weight objects, using suction, for manipulation. Such objects may include glass, plastic, etc. Commonly used because of its virtues of reduced object slide slipping while within the grasp of the vacuum cup. See End-Effector.

Velocity Level: The measure of variation of joint position over time. Single integration yields the overall change in position. Single differentiation yields the change in joint speed over time. Refer to acceleration-level and position level.

Vertical Stroke: The amount of vertical motion of a robot arm from one elevation to the other.

Vision Guided: Control system where the trajectory of the robot is altered in response to input from a vision system.

Vision Sensor: A sensor that identifies the shape, location, orientation, or dimensions of an object through visual feedback, such as a television camera.

VLSI (Very Large Scale Integration): Combining multiple components onto one chip.

Welder: A worker who joins metals together through the use of heat.

Work Cell: Pieces of equipment within close proximity that all work on the same part.

Work Envelope: The set of all points which a manipulator can reach without intrusion. Sometimes the shape of the work space, and the position of the manipulator itself can restrict the work envelope.

Work in Progress: An accounting term used to express the value of material taken up continuously by the work process.

Work-Piece: Any part which is being worked, refined, or manufactured prior to its becoming a finished product.

Workspace: The area the robot can reach to perform operations. A portion of the maximum reach space.

Work Station: A place that the parts move to in order to be worked on.

World Model: A three dimensional representation of the robot's work environment, including objects and their position and orientation in this environment, which is stored in robot memory. As objects are sensed within the environment the robot's controller system continually updates the world model. Robots use this world model to aid in determining its actions in order to complete given tasks.

Wrist: A set of rotary joints between the arm and the robot end-effector that allow the end-effector to be oriented to the work-piece. In most cases the wrist can have degrees of freedom which enable it to grasp an object with roll, pitch, and yaw orientation. See Arm, End-effector, Roll, Pitch, Yaw, and work piece.

XYZ Coordinates: A reference to the most common names given to the lines forming a Cartesian solid.

Yaw: Rotation of the end-effector in a horizontal plane around the end of the manipulator arm. Side to side motion at an axis. See Roll and Pitch.

