

OMNI-WRIST



About PaR Systems

PaR Systems is an integrated group of businesses that specialize in uniquely engineered automation and material handling solutions.

Headquartered in Shoreview, Minnesota, PaR serves customers worldwide.



Business Segments

Robotics:

- ▲ Aerospace, Custom Integrated Processes
- ▲ DOE, Hazardous Material Management
- ▲ Corps of Engineers, Specialty Heavy Handling Equipment – Ederer
- ▲ Food & Beverage Material Handling
- ▲ Industrial Manufacturing
- ▲ Life Sciences/Medical Manufacturing
- ▲ Marine

Defense:

- ▲ Shipboard Automation and Handling – Jered

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BREAKTHROUGH TECHNOLOGY

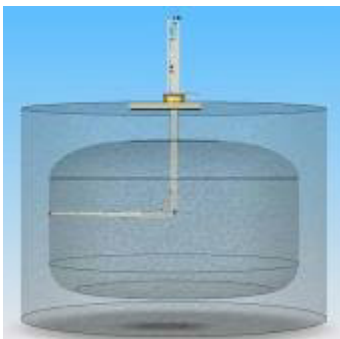
The *Omni-Wrist* is an innovative, high-dexterity, singularity-free wrist head that is best suited in applications that require a compact, dexterous and flexible head for positioning tools in any orientation.

Traditional wrists usually tilt the tool in one or two axes, called pitch and roll, and typically consist of a simple clevis that produces pitch motion and a base that rotates. Although this design is rugged and easily designed and manufactured, it is prone to jamming and cable management problems.

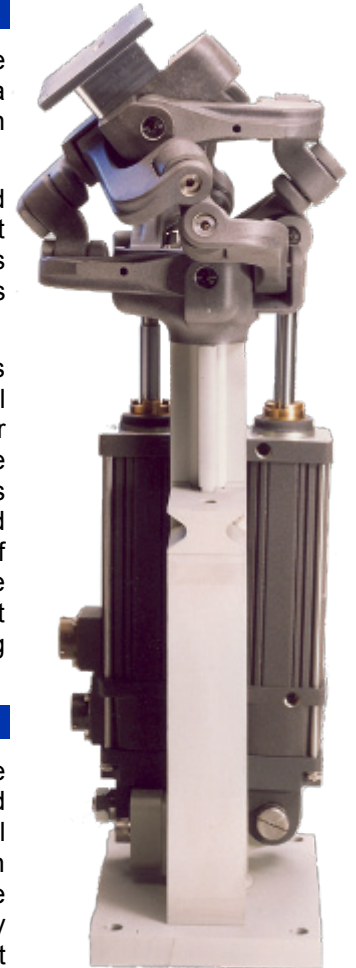
The *Omni-Wrist* has a low profile, fewer parts, and incorporates a true 180° hemispherical motion without singularities or gimbal lock that would restrict movement of the tool. Two actuators, for pitch and yaw, drive the arms up and down while double preloaded bearings connect the links to each other. The arms drive the associated links above them. Through kinematics and structure, the links move the output well beyond the range of conventional wrists. The *Omni-Wrist* consists of only three identical links repeated to form a double universal joint structure. The *Omni-Wrist* mimics the human wrist by rolling about itself rather than simply rotating, as in standard wrists.

OMNI-WRIST USE IN TANK CLEANING SYSTEM

PaR Systems has incorporated the *Omni-Wrist* into a prototype mobile tank cleaning system. The *Omni-Wrist* is being utilized at the end of a commercial boom arm to perform critical functions required for the final cleaning of one million gallon tanks formerly used to store radioactive sludge. Since the cleaning system is deployed into the tanks through a relatively small opening at the top of the buried tanks, the compact design of the *Omni-Wrist*, its full hemispherical travel and the use of only two drive hydraulic cylinders make it an ideal fit for this application.



In the tank cleaning system, the first function of the *Omni-Wrist* is to direct remote high pressure spraying for heel removal (the heel is the hardened remaining sludge that is left in the tank following sluicing and pumping operations). The high pressure spraying requires the wrist joint to remain stiff yet maneuverable during spraying operations which is well suited to the *Omni-Wrist's* design. The second function of the *Omni-Wrist* is to direct low pressure acid spray, to further break down the heel. This operation requires the spray to be applied where needed to minimize the amount of acid to be used. The final function of the *Omni-Wrist* is to deliver a vacuum recovery system to the floors and walls of the tank interior to collect the final wash-down liquids as well as solids. The vacuum system uses a 3" ID flexible hose. Since the *Omni-Wrist* has a hollow center, the hose is routed through the center of the wrist body, allowing the overall dimensions of the collection system to be minimized and the vacuum hose routing to be simplified. In this application, the *Omni-Wrist* is constructed of high strength steel with good corrosion resistant properties to survive in the harsh environment (both operational and chemical) it is deployed.



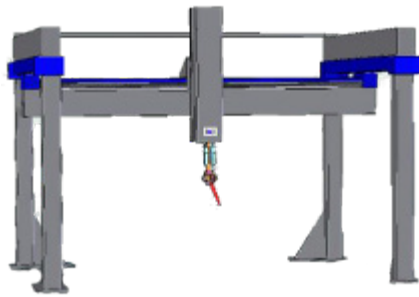
Design by Ross-Hime Designs

OMNI-WRIST



OMNI-WRIST¹ APPLICATIONS

The Omni-Wrist is ideally suited for a variety of applications:



Waterjet cutting
Laser cutting
Light material removal
Coating application / removal
Flexible fixturing for part positioning



Antenna pointing
or other tracking
applications



Water fountain animation



Tank sluicing

OMNI-WRIST FEATURES

- Simple construction with low cost
- Low power, low weight, small size
- Dexterous half hemispherical coverage
- Singularity-free motion
- Hollow center for routing cables and hoses eliminates umbilical entanglement
- Jam-resistant
- Elimination of gearing
- Preloaded bearing design

OMNI-WRIST TYPICAL SPECIFICATIONS

Height	18-28"
Diameter	8-18"
Weight	25-50 lbs.
Payload Capacity	5-25 lbs. @ specified resolution; 30-75 lbs. maximum
Pointing Envelope	180° Hemisphere + 5° Past Horizon
Travel Rate	Full range in less than 5 seconds
Positional Resolution	216 arc seconds (.06°)
Positional Accuracy	(0.5°)
Actuator Type	Linear, Exlar or Rotary gear-head
Limit Switches	Hall effect sensor at all ends of travel; mechanical stops in actuators
Home Position Sensor	Fiber optic displacement sensor
Through Hole	2-5"
Construction	Titanium, Aluminum, Stainless Steel

¹ The *Omni-Wrist* is the invention of Ross-Hime Designs. PaR Systems has an exclusive license for use of the Omni-Wrist from Ross-Hime Designs, Inc.

OMNI-WRIST



COMPARISON OF GROUND BASED VERSUS OVERHEAD OPERATION

Pan & Tilt Gimbal Azimuth / Declination:

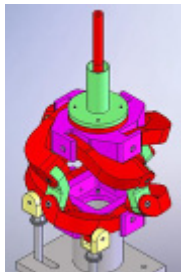
- Ideal for horizontal operation mounted on ground or tower
- Overhead Issues:
 - Straight line tracking across room and below unit very difficult
 - Singularity zone difficult to manually control
 - Near singularity large pan travel angles are required
 - Undesired camera flips

Omni-Wrist:

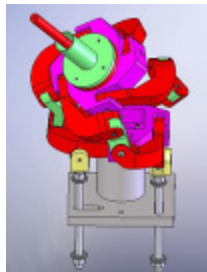
- Ideal for overhead operation mounted in ceilings of structures
- Overhead Advantages:
 - Full hemispherical coverage directly below makes straight line tracking easy
 - No singularity
 - Manual positioning intuitive
 - Minimized camera roll
 - Elimination of umbilical entanglement

OMNI-WRIST IV TEST ORIENTATIONS

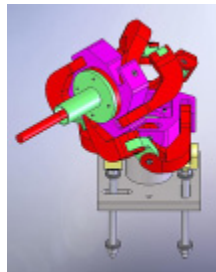
Dexterous machining wrist development and its applications to 5-axis robotic milling, drilling and waterjet.



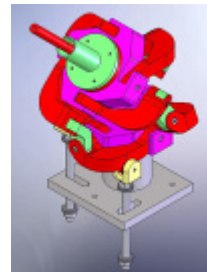
Neutral position for principle & compound bias planes



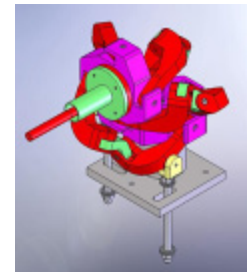
45° in compound bias plane



90° in compound bias plane



45° in principle plane



90° in principle plane

STIFFNESS TEST FOR PAR SYSTEMS OMNI-WRIST IV DESIGN

Force applied at various wrist orientations. Deflection measured with a laser tracker to determine stiffness and lost motion.



OMNI-WRIST KINEMATICS AND HIGH ACCURACY ENHANCEMENT

- Simplified closed function kinematics
- Extensive MEC[®] (Mechanical Error Compensation) model to achieve 30-60 arc second accuracy
- Accuracy depends on mapping density
- Measure in multiple spheres to determine position and orientation

