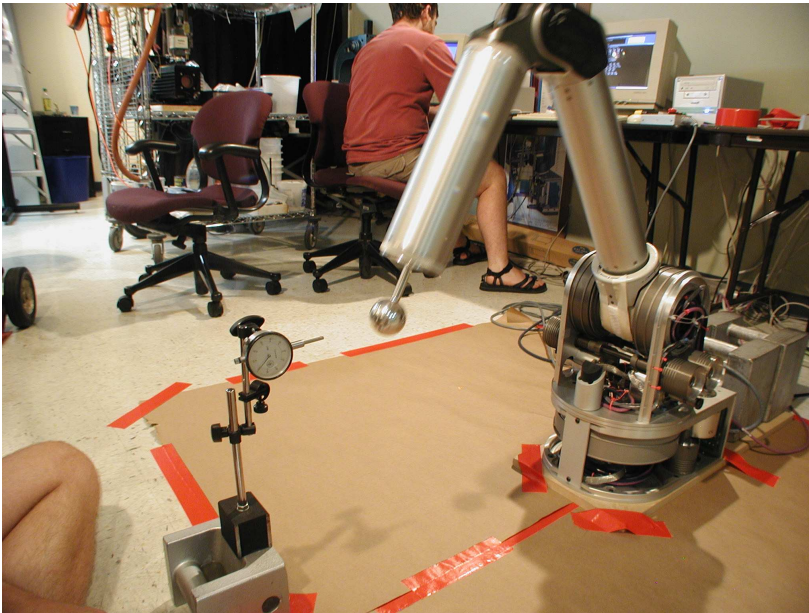


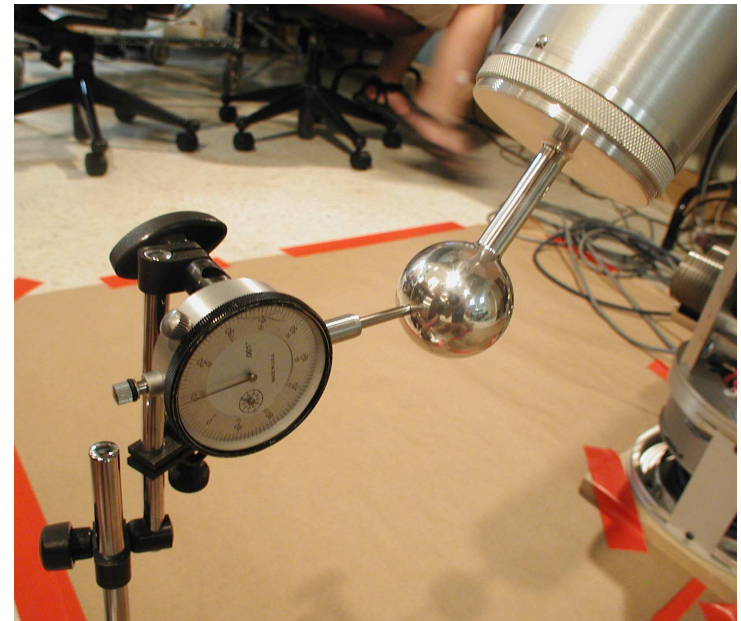


1: Specifications & Performance Studies: Repeatability Setup

[http:// www.barrett.com](http://www.barrett.com)
Phone: 617-252-9000



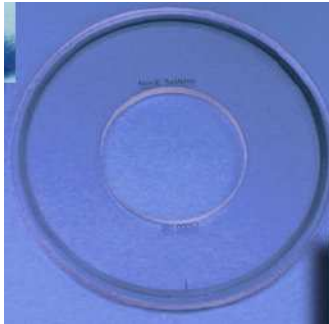
a) WAM arm moving towards dial indicator



b) WAM arm touching dial indicator



1: Specifications & Performance Studies: Repeatability Data



a) Photograph of motor encoder scale.
The encoder provides for 40,000 counts per motor revolution



Encoder resolution: 40,000 counts/rev
Motor resolution: 0.009 deg/count
Joint 1 transmission ratio: 30:1
Ideal joint resolution: .0003 deg/count
Approximate moment arm: 1 m
Ideal repeatability: 0.005 mm

Repeatability in practice

Large Movements

Position <i>in</i>	Absolute Error		Start Position	Mid Position	End Position	Full path swept
	<i>in</i>	<i>mm</i>				
0.1	< start					
0.103	0.003	0.076	J1	0	180	0
0.106	0.003	0.076	J2	90	-90	90
0.107	0.001	0.025	J3	0	180	0
0.109	0.002	0.051	J4	90	-90	90
0.1095	0.0005	0.013				
0.11	0.0005	0.013				
RMS	0.0020	0.050				
AVG	0.0017	0.042				
MAX	0.003	0.076				

Small Movements

Position <i>in</i>	Absolute Error		Start Position	Mid Position	End Position	Full path swept
	<i>in</i>	<i>mm</i>				
0.1185	< start					
0.1195	0.001	0.025	J1	0	0	0
0.115	0.0045	0.114	J2	45	-45	45
0.119	0.004	0.102	J3	0	0	0
0.118	0.001	0.025	J4	90	140	90
0.114	0.004	0.102				
0.117	0.003	0.076				
0.113	0.004	0.102				
RMS	0.0034	0.085				
AVG	0.0031	0.078				
MAX	0.0045	0.114				



1: Specifications & Performance Studies: Accuracy Setup

Notes regarding accuracy data:

It is important to note that the repeatability data is a better measure for calibrated accuracy than is uncalibrated accuracy.

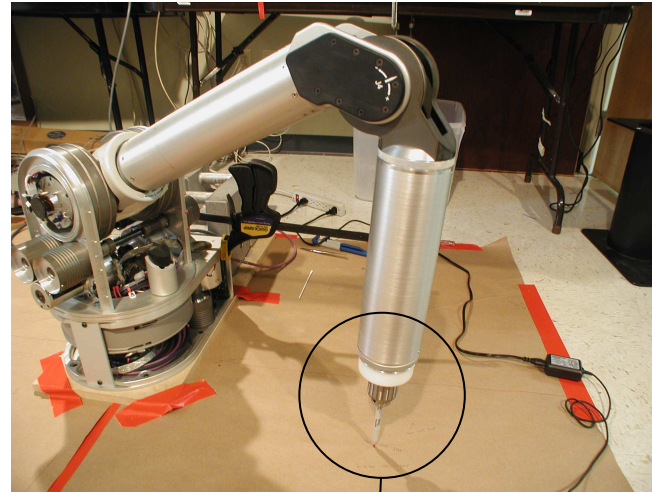
Uncalibrated accuracy was measured as shown in the figures to the right. A pen attached to the outer link was used to plot points on paper taped to the floor and the WAM base was secured to the floor.

Potential sources of measurement error include:

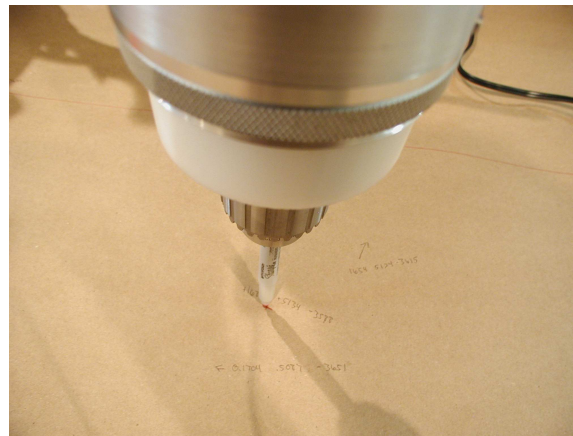
- the floor was assumed to be flat
- physical measurement error with rulers & T-squares
- physical measurement of WAM origin difficult to measure accurately

Sources of system error (calibration error) include:

- transmission ratio errors
- tolerance stack-up of parts
- tool location measurement (tip of pen)



a) WAM – single link



b) close-up of end-tip



c) WAM – dual link



1: Specifications & Performance Studies:

Item 5: Accuracy vs. Reach

Single outer link system

Point Label	Measured (mm)			Recorded (mm)			Absolute Error (mm)			X-Y planar error (mm)	Total error (mm)
	X	Y	Z	X	Y	Z	X	Y	Z		
a	-446	-779.5	-365	-439.8	-797.8	-345.2	6.2	18.3	19.8	19.3	27.7
b	-407	-811.5	-365	-396.3	-814	-352.6	10.7	2.5	12.4	11.0	16.6
c	-344.5	-493	-365	-348.8	-500	-357.6	4.3	7	7.4	8.2	11.1
d	-166	-174.5	-365	-170.2	-177.5	-364.6	4.2	3	0.4	5.2	5.2
e	156	-180	-365	159.8	-183.4	-364.2	3.8	3.4	0.8	5.1	5.2
f	378.5	-467.5	-365	380.6	-470.9	-361.6	2.1	3.4	3.4	4.0	5.2
g	636.6	-760.4	-365	651.3	-765.7	-339	14.7	5.3	26	15.6	30.3
h	-348	850.5	-365	-351.8	862.2	-348.4	3.8	11.7	16.6	12.3	20.7
i	15	181.5	-365	16.3	190.3	-364.4	1.3	8.8	0.6	8.9	8.9
j	167.5	501.5	-365	168.7	513.4	-358.8	1.2	11.9	6.2	12.0	13.5
j	167.5	501.5	-365	165.4	512.4	-361.5	2.1	10.9	3.5	11.1	11.6
j	167.5	501.5	-365	170.4	508.7	-365.1	2.9	7.2	0.1	7.8	7.8
k	648.5	787.4	-365	654.9	800.3	-336.9	6.4	12.9	28.1	14.4	31.6
k	648.5	787.4	-365	647.9	799.7	-348.1	0.6	12.3	16.9	12.3	20.9
k	648.5	787.4	-365	659.8	791.1	-346.6	11.3	3.7	18.4	11.9	21.9
l	618	10.5	-365	627.7	10.3	-355.1	9.7	0.2	9.9	9.7	13.9
l	618	10.5	-365	623.8	8.6	-360.7	5.8	1.9	4.3	6.1	7.5
l	618	10.5	-365	622.3	15.4	-361.2	4.3	4.9	3.8	6.5	7.5
						RMS	6.5	8.6	13.3	10.8	17.1
						AVG	5.3	7.2	9.9	10.1	14.8
						MAX	14.7	18.3	28.1	19.3	31.6

Uncalibrated

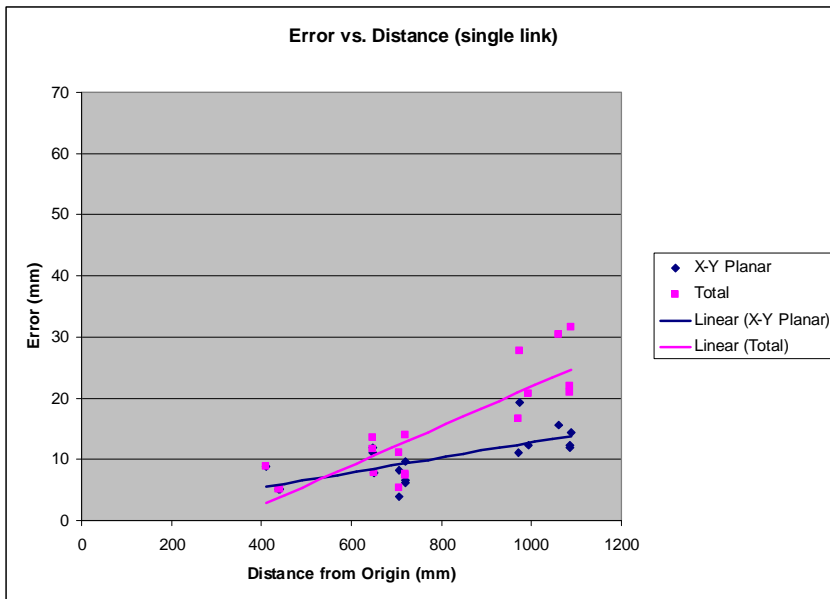
Dual outer link system

Point Label	Measured (mm)			Recorded (mm)			Absolute Error (mm)			X-Y planar error (mm)	Total error (mm)
	X	Y	Z	X	Y	Z	X	Y	Z		
e	156	-180	-365	171.1	-180.7	-365	15.1	0.7	0	15.1	15.1
g	636.6	-760.4	-365	675.5	-754.3	-332	38.9	6.1	33	39.4	51.4
k	648.5	787.4	-365	649.2	833	-325.8	0.7	45.6	39.2	45.6	60.1
k	648.5	787.4	-365	654.1	814.2	-347.4	5.6	26.8	17.6	27.4	32.5
k	648.5	787.4	-365	632.2	830.7	-345.1	16.3	43.3	19.9	46.3	50.4
l	618	10.5	-365	644.6	33.6	-349.3	26.6	23.1	15.7	35.2	38.6
l	618	10.5	-365	628.7	25.8	-367.5	10.7	15.3	2.5	18.7	18.8
l	618	10.5	-365	626.4	43.2	-362	8.4	32.7	3	33.8	33.9
						RMS	19.1	28.6	21.2	34.4	40.4
						AVG	15.3	24.2	16.4	32.7	37.6
						MAX	38.9	45.6	39.2	46.3	60.1

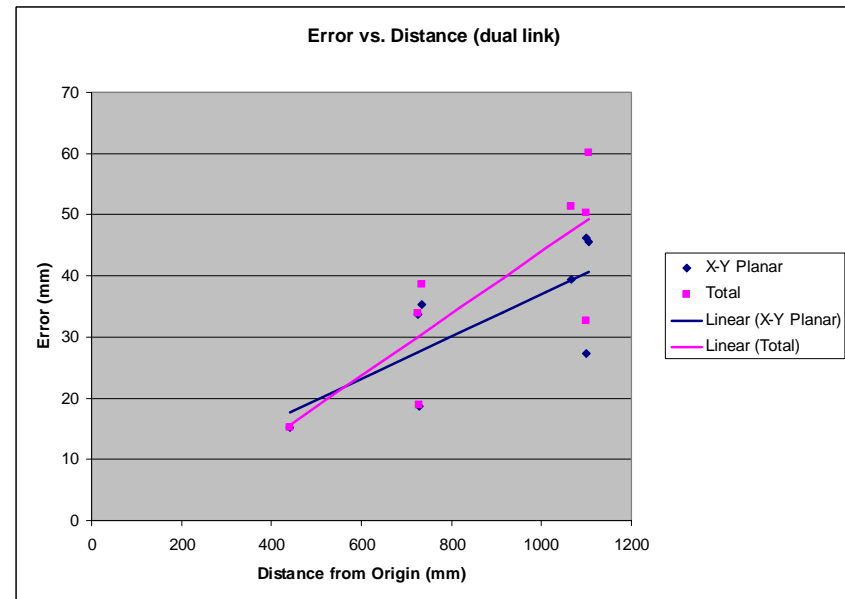
Uncalibrated



1: Specifications & Performance Studies: Item 5: Accuracy vs. Reach



a) Uncalibrated accuracy of single-link system



b) Uncalibrated accuracy of dual-link system