# QUICK LOOK DATA FROM SP8 SUIT MEASUREMENT

# BY THORNTON KINESIMETER

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CB

3·9·1979

This data should be restricted to local JSC use until more comprehensive analysis has been completed.

Unsuited, Buchli
Max. Reach
Ea. sm. div. = 1 cm.
M.S. 3.9.79

STS Suit 4 PSI Buchli
Max. ——, Functional - - - - Reach
$X_o$ ref. is midline Scyes, $Y_o$ is midline
Each sm. div. = 1 cm. M.S. 3.9.79

A one day test of the SP8 suit (STS) was run August 30, 1979, at Southwest Research Institute in San Antonio, Texas, to obtain a limited amount of reach and force data for JSC engineering purposes and especially work station design for STS tile repair. Overall conduct of the test was under my direction. James F. Buchli was the subject. Other support and monitoring personnel included: John T. Jackson (EW5), James L. Lewis (EW5), Alan M. Rochford (EC5), Randolph H. Hester (EC5), Brian M. Pacheco (ILC), John Cater, Dean Davis, and Jackie Hipp of Southwest Research Institute.

The system which collected the data has been under design and development by me since 1974, has been financially and otherwise supported by Spacecraft Design (John T. Jackson and more recently James L. Lewis), and was constructed and tested by Southwest Research Institute (John Cater, Dean Davis) over the past 2 years.

It is an original system in concept and operation which continuously tracks, by optics and a three-camera video system, one or more illuminated points. Location is determined (mean error $\sim \pm 1$ cm) every 50 ms in at least two orthogonal planes and is stored (RAM, discs, tape, etc.). Computer and software then reconstructs the three-dimensional path in space from which position, velocity and acceleration may be derived. A cable arrangement and isokinetic (constant speed, maximum force) ergometer allows continuous measurement of maximum force along most axes at selected velocities. This data is simulataneously stored with position data such that one can also develop three-dimensional force patterns.

This system was designed around supporting computer/software programs but money has not been available to complete software hence much of the data reduction here was manual. An intergral part of the original concept was computer interaction of the collected data with proposed hardware designs. James L. Lewis has a program (PLAID) which will do this. The data collected on August 30 ($>10^5$ K bytes) is now being processed and James L. Lewis will be able to analyze, plot and interface the data in a more comprehensive fashion in the near future. As resources become available

the kinesimeter will be moved to a dedicated lab in Building 29 here at JSC and interfaced with the PLAID system for on-line storage and analysis.

MEASUREMENTS MADE

After calibration and validation of the system, the suit was donned in the station where familiarization runs and a single unpressurized maximum reach run was made. Data was collected as follows: A tracking light was attached to the lateral aspect of the glove thumb and projected ~ 2 cm beyond thumb tip. The subject made a series of up and down sweeping motions to cover the entire area which he could reach with maximum effort. This is somewhat analogous to "painting" one's extreme reach envelope, for up to 6 x $10^3$ points may be collected. A zero axis reference light was attached above the midline of the PLSS and all lateral data is referred from this to the midpoint of the scye openings as zero reference for the enclosed plots.

To prevent interference from the donning station all measurements were made with the suit HUT crosstrapped to an L-shaped bracket which maintained a fixed position while allowing complete freedom of the arms. The suit was typically depressurized between runs which usually lasted 5 minutes or less. During data takes the subject carried the weight of a lightened PLSS and DCM normally used in the WIF but sat with the PLSS supported between times.

A series of maximum right and left arm reach envelopes were run with the suit at 4 psi.

These were followed by functional reach envelopes of each arm in which the subject repeatedly swept his arm within a working range which he felt was comfortable and which could be sustained.

At the request of suit engineers, a two-handed functi onal reach measurement was made in which the extended fingers of the left hand were grasped by the right and a comfortable work envelope was swept out.

A series of maximum effort strength measurements were done in which the subject stood unsupported with suit pressurized and feet usually in the restraint location (measured) and made maximum reach, maximum effort "pulls" and "pushes" with the left arm at shoulder level and along $45^{o}$ radials from side to side (front). A single vertical pull down was measured and a series of pull-ups at various radials was made. Foot position was sometimes varied for maximum stability to compare to the standard foot position. Strength tests were abbreviated for lack of test time.

WARNING

The above is a cursory description of the testing. Details should be discussed before application of the data. Data points are felt to be accurate to better than ±1 inch, however, some minor revisions may occur since manual reduction and tracing was done. Most importantly, this is one-g data from a single subject and must be used accordingly. The reach data obviously refers to arms only, not total reach either in one-g or weightlessness. However, I believe this is the most comprehensive data of its kind to date on any suit and should be followed with additional studies to increase the suit/subject data base.

## DATA AND ITS REDUCTION

Figure 1 shows the basic reference system which is non-standard. A reach envelope is generated by swinging the arm in up/down arcs as in Figure 2. The arcs are more or less continuously tracked, a sample every 50 ms, and the paths stored in memory. An algorithm is available for plotting all crossing paths through a selected Z plane as in Figure 3. Any path which (1) crosses the plane, and (2) has a point with Z ±1 cm, is plotted. Figure 4 is typical of such a plot. It has been found that only the most peripheral points represent the maximum reach while the majority are trajectories for sweeps elsewhere in the envelope. These peripheral points are then connected by a continuous curve and traced on graph paper.

Verification of calibration and data quality was made by swinging a series of fixed radii circles in the same position as the suit was placed, before and after data was taken. These were processed and plotted and errors measured. The 100 percent error bands were 3% wide at 100 cm radius and 2-1/2 percent wide at 50 cm with mean errors on the order of 1 cm.

Appendix A contains curves from the standing reach test of the suit at 4 psi with the torso fixed in position.

They inscribe intersection of the reach envelope with a series of horizontal planes 10 cm apart from top to bottom of the reach envelope and as such enclose the area which can be reached at a given height. The major reference line (X = 0) is the midpoint of the suit scyes; i.e., approximately the shoulder joint while the midline (Y = 0) is suit midline. Solid lines are maximum reach while dotted lines are functional reach; i.e., the limits of the volume within which the subject felt he could comfortably perform a sustained task. This is in contrast to the maximum reach which often required considerable physical effort.

A shirt sleeve maximum reach envelope is included with curves at levels which correspond to the top, middle and bottom of the suit envelope. Scale factor is the same for these curves but the reference was not rectified to be coincident with suit reference.

Also included for comparisons are two maximum reach curves from an A7L suit, 3.8 psi with a different subject. The levels of these curves correspond to approximately -20 and -40 of the SP8 curves and scale factor is the same.

Appendix B contains Z level or horizontal reach curves in the pressurized SP8 suit. A functional two-handed task was simulated by clasping the fingers of one hand with the other and moving throughout a comfortable work envelope. This data while subjective was also very consistent.

Appendix C contains only three X or transverse vertical planes. These were

manually plotted from the corresponding X points on the Z planes and represent the working area which can be reached in front of the crewmen; e.g., it would represent the working surface available on the STS from a crewman parallel to it and separated by the distances shown. These three curves represent the prime working area from DCM ( X ~40 cm) to maximum reach (X ~80 cm), however, as time allows, all planes will be plotted and distributed.

Strength data is still in work and will be plotted and distributed in the next few days.

COMMENTS ON TEST AND DATA

This quantitative data confirms that the Shuttle suit is a marked improvement of the A7 as regards reach. The fact that the subject spent over 6 hours in it, often doing maximum effort tasks, and was functioning well at the end also speaks well for it. At the mid shoulder level (Z = 0) the reach compares well with unsuited reach in the forward areas but cannot cover the side and back reach capacity of an unsuited subject. A portion of this may be simple mechanical interference from the HUT and DCM. The latter is 10 cm thick. Upper and lower suit reach is restricted and unsuited reach capacity, X = +65, -50, is considerable at these levels. The result is a constricted work area.

Several apparent discrepancies in the data requires comment. First, there is a significant vertical displacement of the right and left envelopes. This is seen most clearly in the X planes where the left is approximately 10 cm below the right. On review of the subject's incoming anthropometric exam a left depression was found. This was consistent with the subject's tendency to lower the left side as noted in the test; i.e., we have a normal subject variation which was reflected in the envelopes.

The subject complained of binding in the right arm bearings during the tests.

Variations are noted in the shape of the right maximum reach envelopes at Z = +10 and X = +50. In Z = +10 there is a hook in the medial portion and the functional exceeds the maximum reach. At the same time in X = 50 the right functional reach was a straight line at its lateral border. All of these would be explained by an intermittant restriction in the right arm.

It is obvious from the functional curves, if they remain the same in weightlessness, a restricted work area will have to be accommodated. This will be especially true for a two-handed repetitive task.

These comments have been based on a sample of one. Data such as this should provide the basis for an analytical design process but the results of any design must still be tested in the most realistic way possible, probably in long WIF sessions in this case.

This data would not have been possible without the aid and support of the several organizations and individuals who participated as well as others.

# Appendix B

Z (horizontal) planes of functional reach for a two-handed task at 10 cm increments above and below mid point of scye openings (Z = 0). X zero reference is also midline of scye openings. Y zero reference is suit midline Scale 1 mm = 1 cm.

Subject J. Buchli in SP-8 suit at 4 psi standing with HUT fixed.

# Appendix C

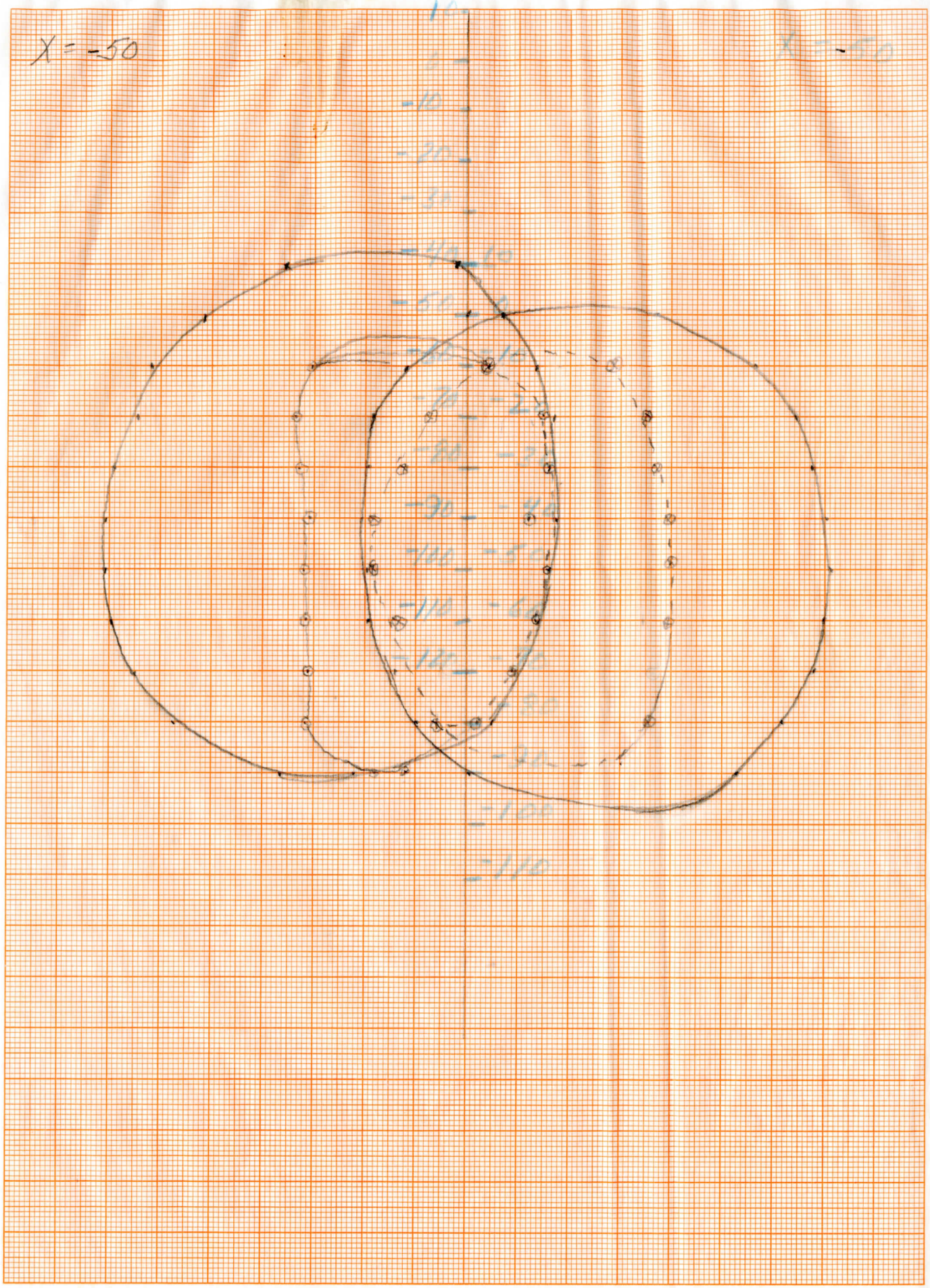
Three vertical transverse (X) planes of maximum and functional reach limits of J. Buchli in SP-8 suit at 4 psi, torso fixed. Z and X zero reference is mid point of scye openings, Y reference is mid line - scale 1 mm = 1 cm. N.B.--display and control assembly extends to X = 40 cm and maximum reach envelope ends at X = 80 cm.

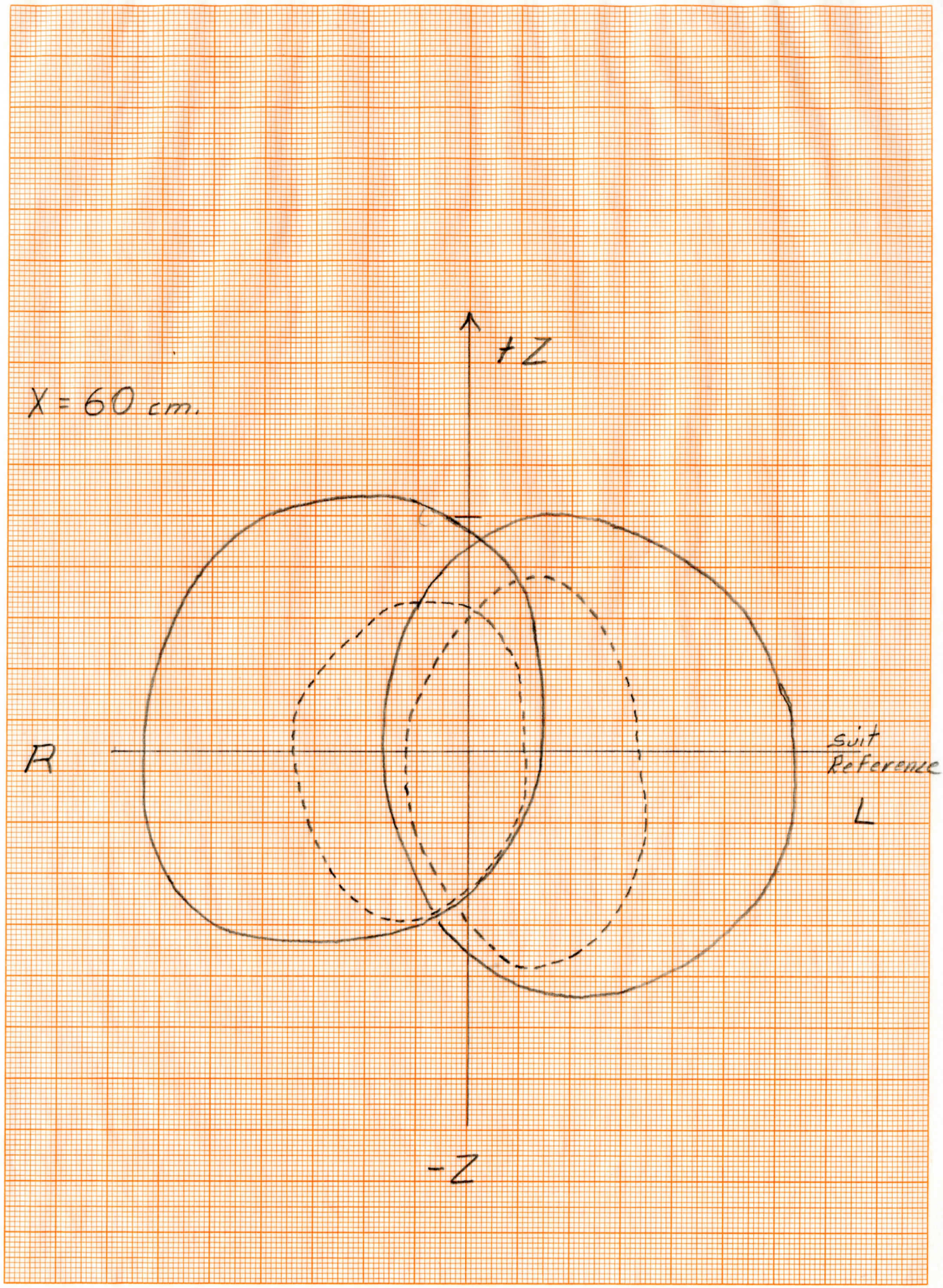
STS Suit 4 PSI Buchli

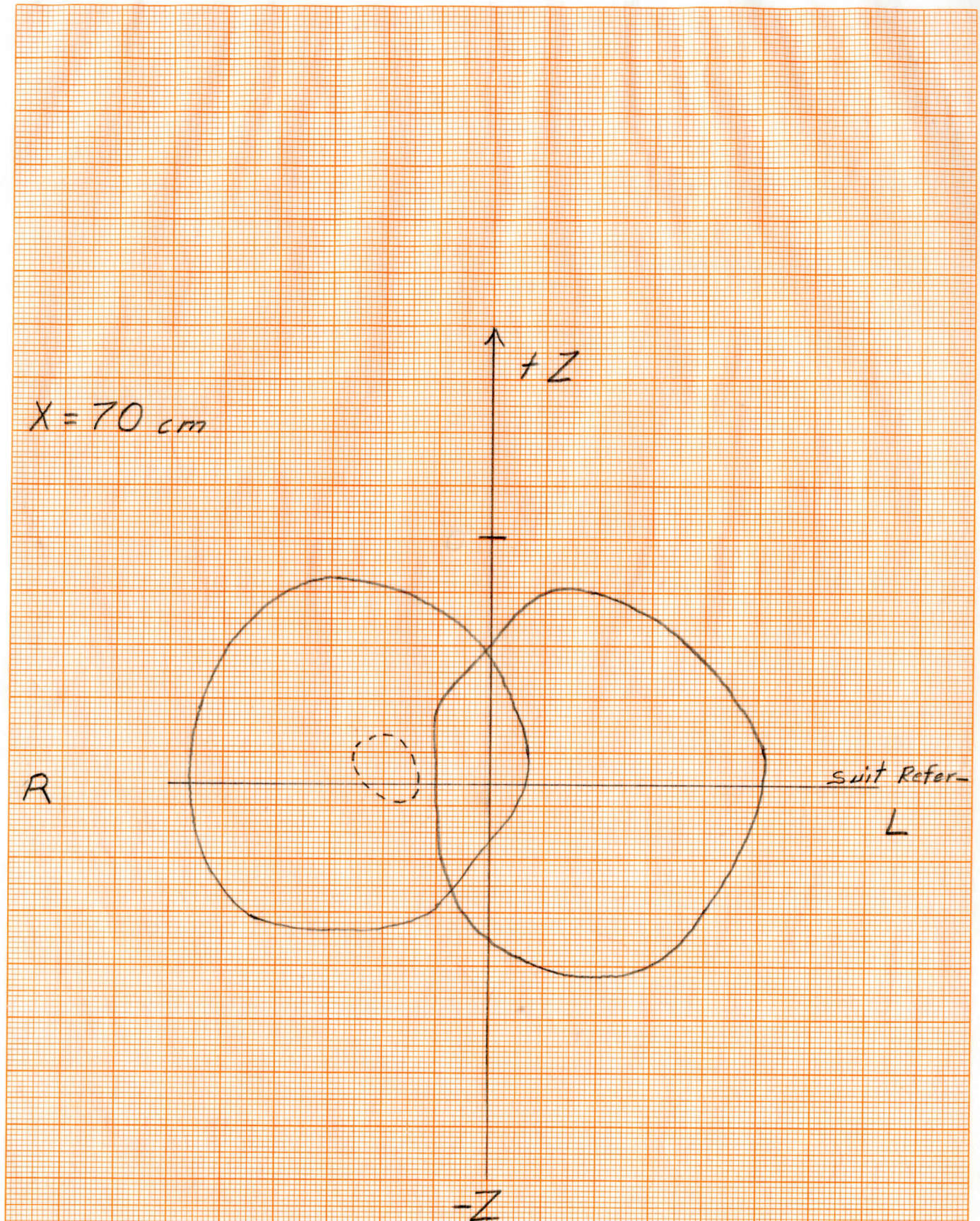
Max ——, Functional --- Reach

$X_o$ ref. is midline Scyes, $Y_o$ is midline

Ea. sm. div. = 1 cm. M.S. 3.9.79



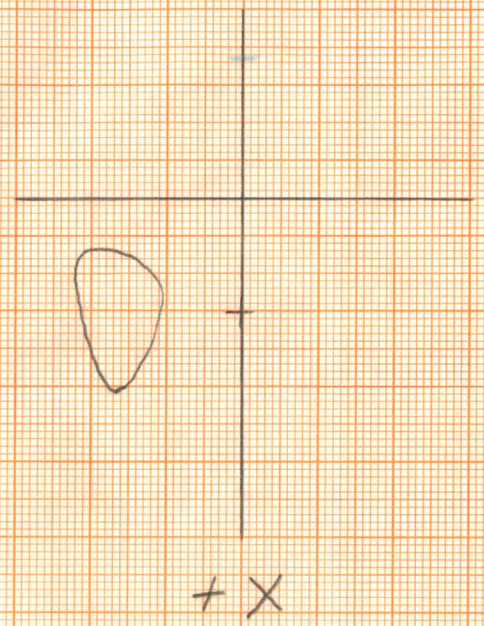





NB - Max reach envelope barely touches X = 80

Z = +65 cm. +15

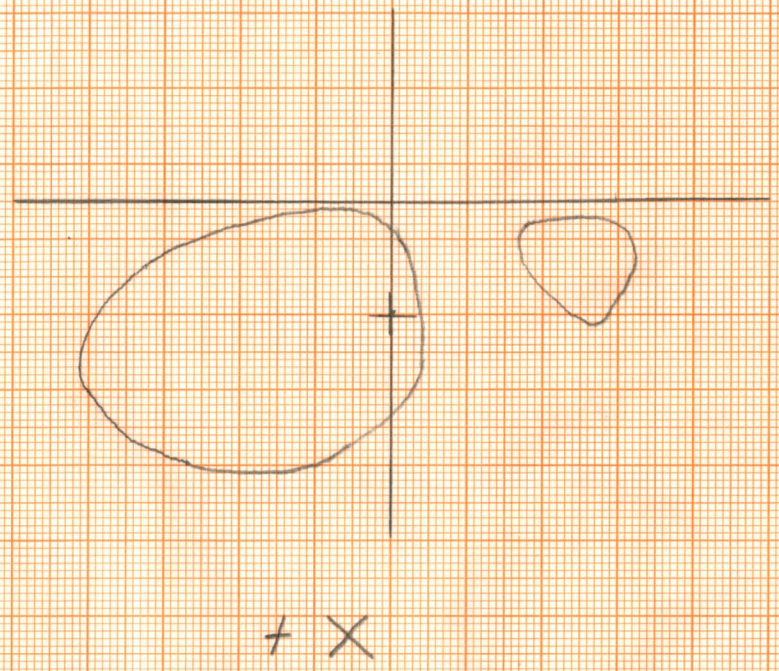
Max ROM Ⓡ + Ⓛ arms —




NB - no points on Ⓛ side reached at this level and no points reached by either side at + 70 cm.

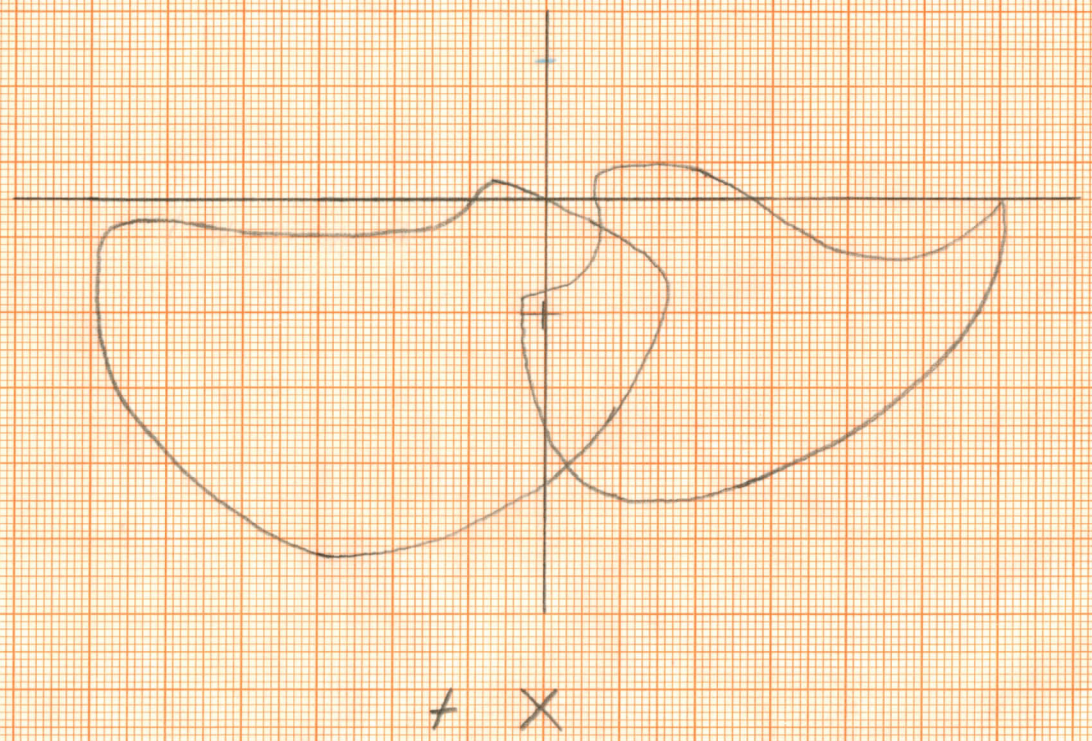
Z = +60cm. +10

Max ROM Ⓡ & Ⓛ



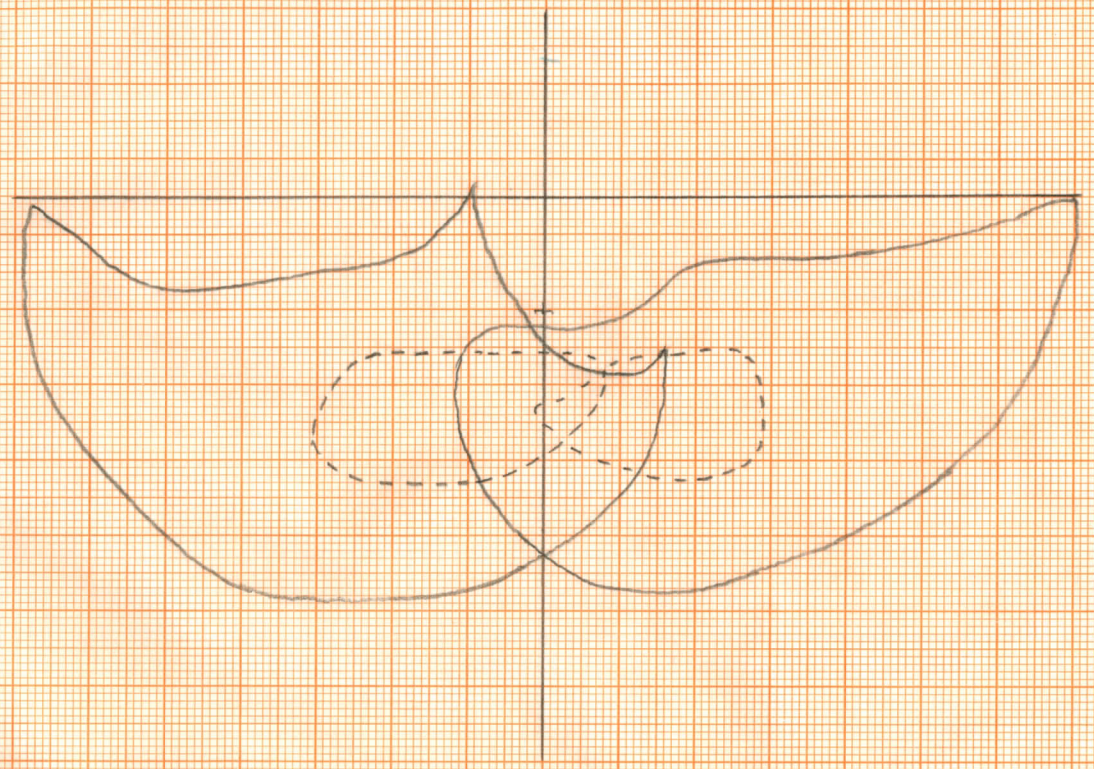
Z = +50cm.

Max ROM Ⓡ & Ⓛ arms ——



Z = + 40 cm -10

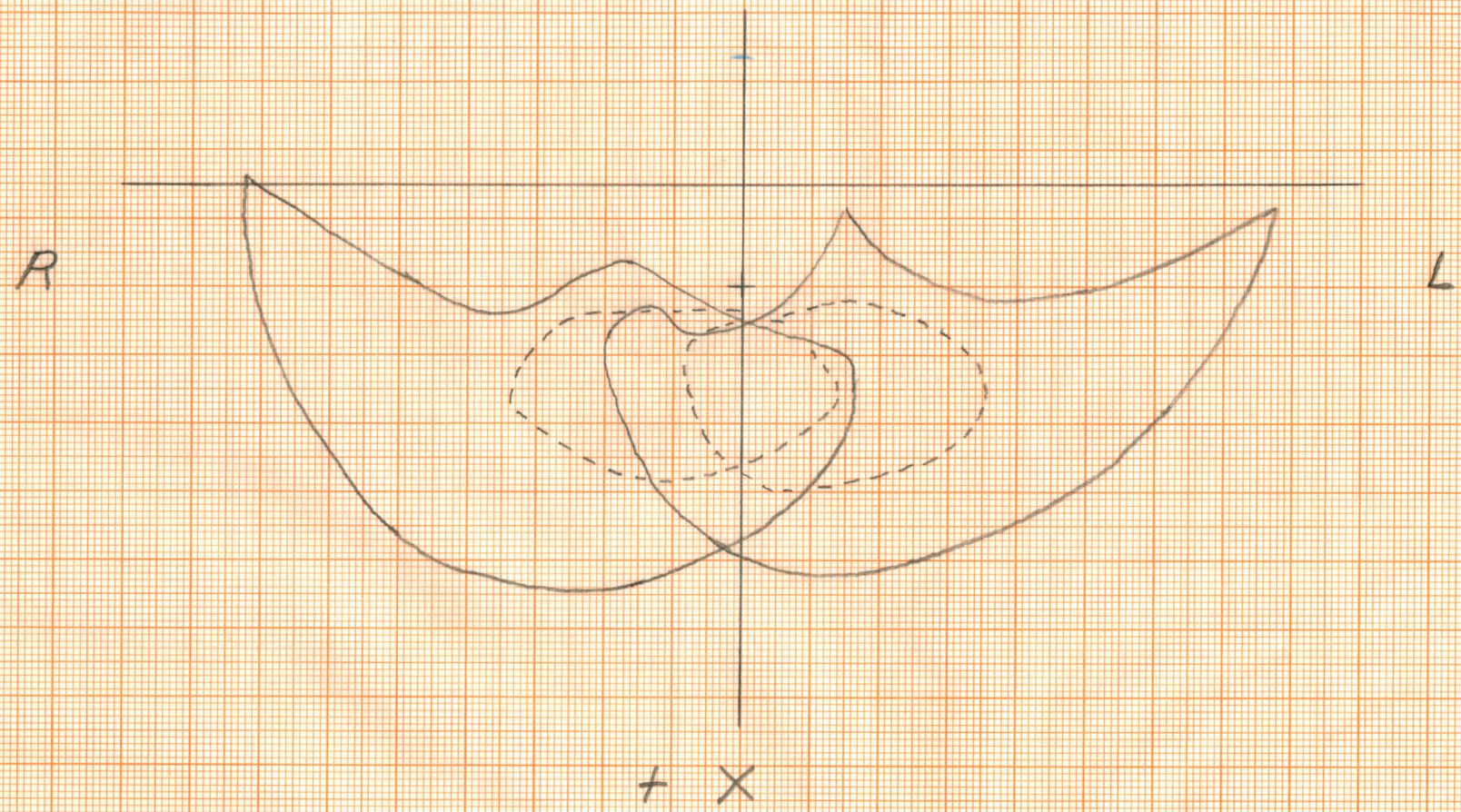
Max ROM (R) + (L)




NB - no functional reach intersections at 10 cm. levels above this

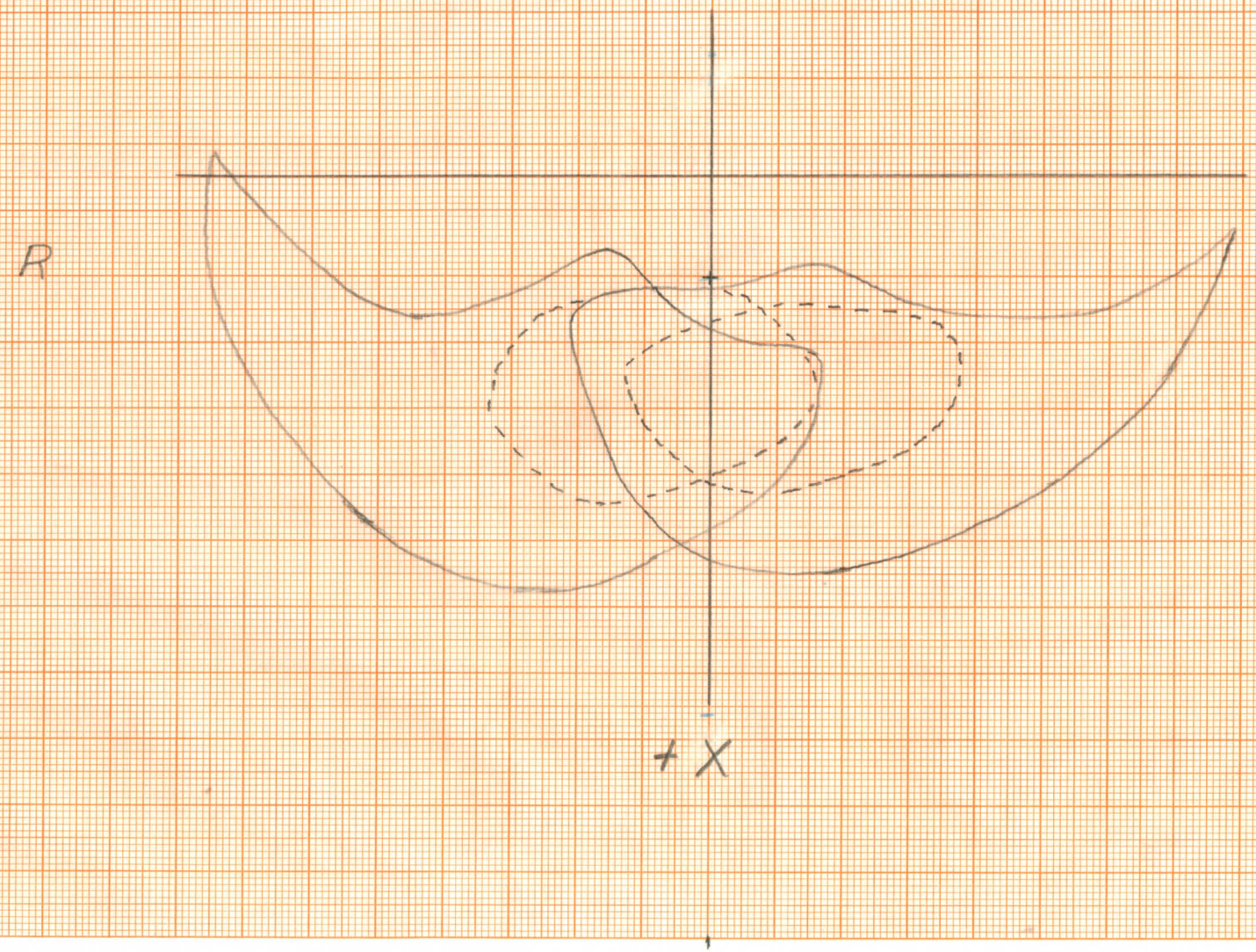
Z = +30 cm. -20

Max. ROM Ⓡ & Ⓛ arms ——



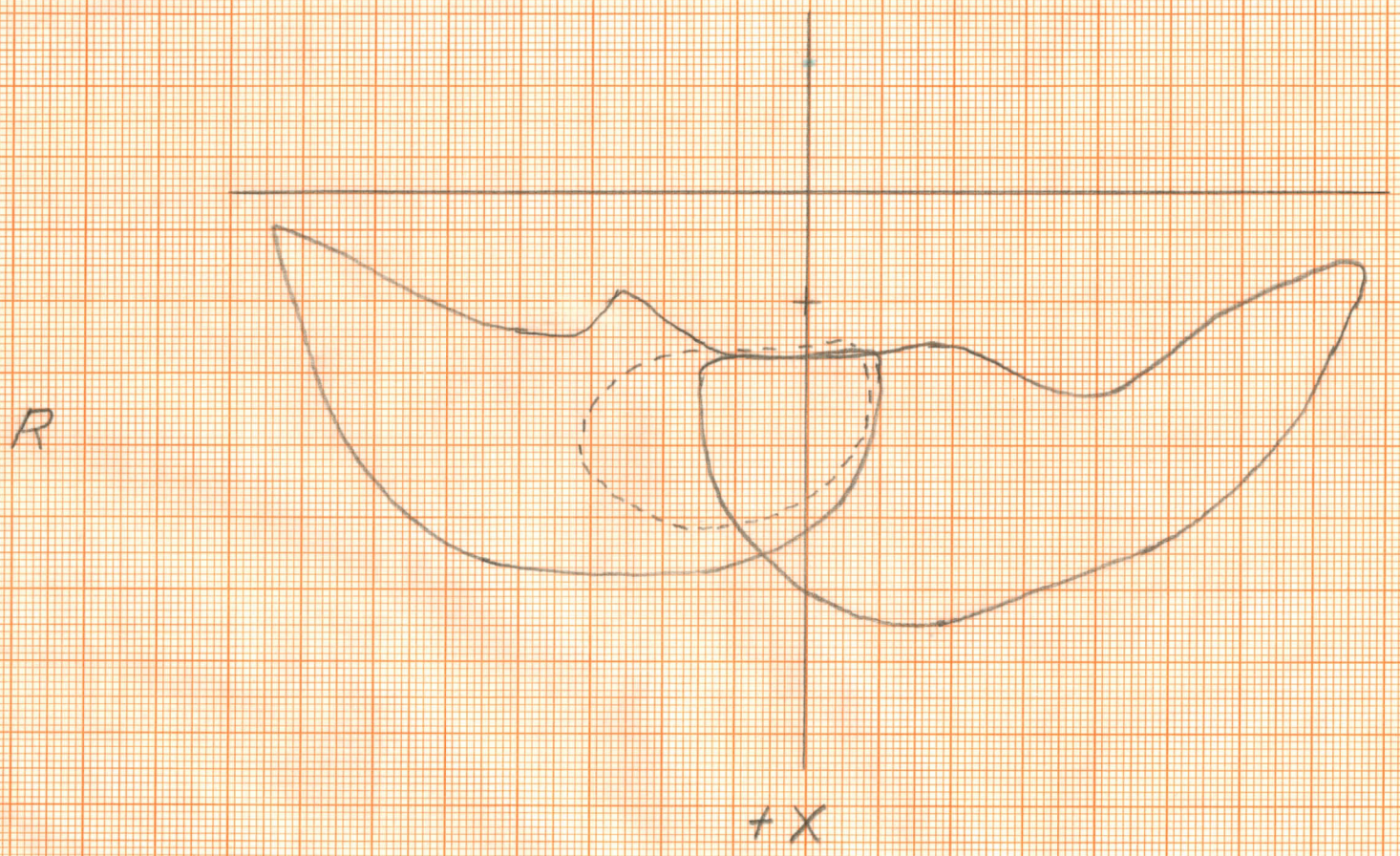
Z = + 20 cm.

Max. ROM (R) & (L) Arms



Z = -20 cm. -7

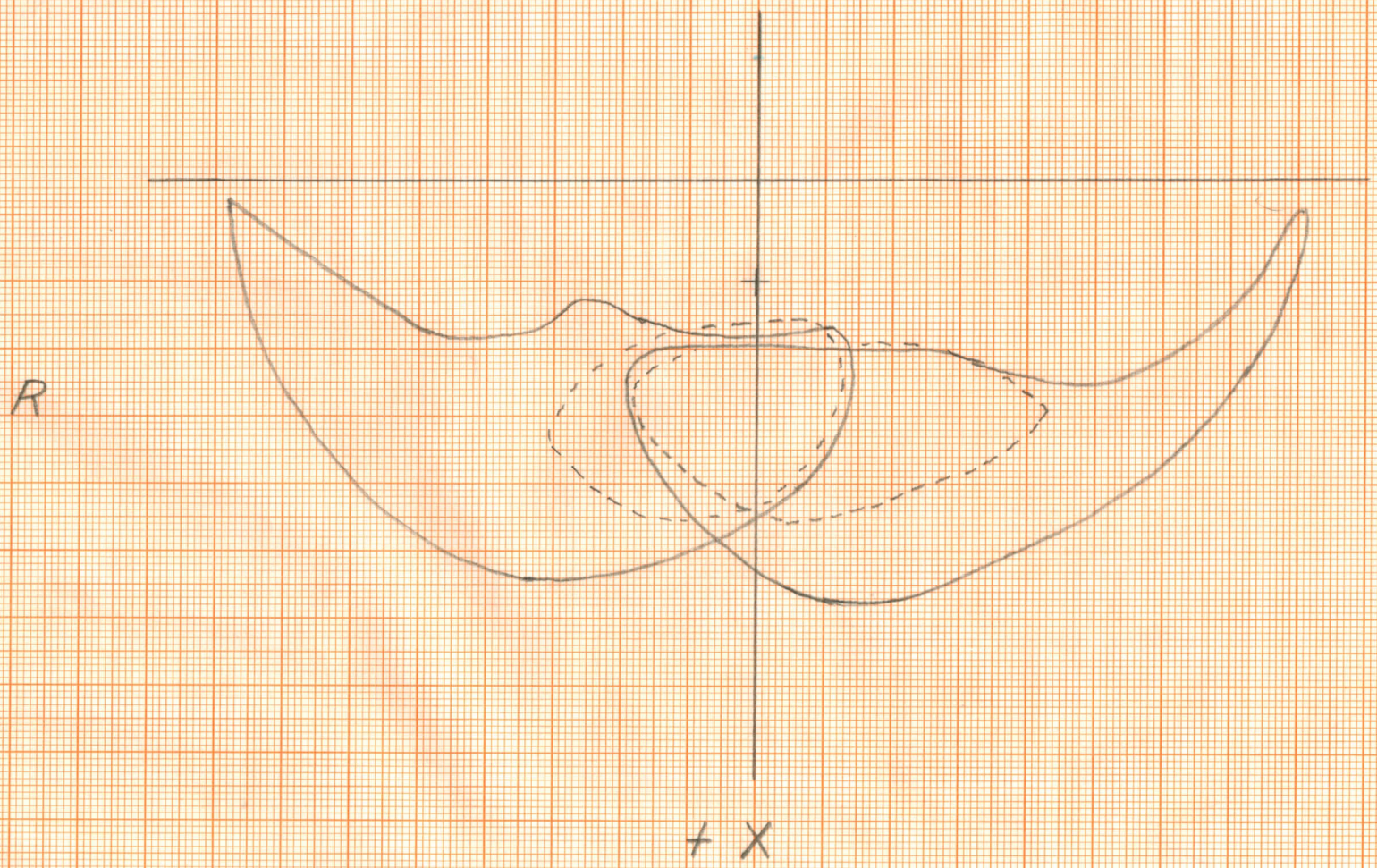
Max ROM Ⓡ & Ⓛ arms




NB - 20 cm. Funct. ROM Ⓛ inadvertantly not plotted - is in work

Z = -10 cm

Max ROM Ⓡ & Ⓛ arms

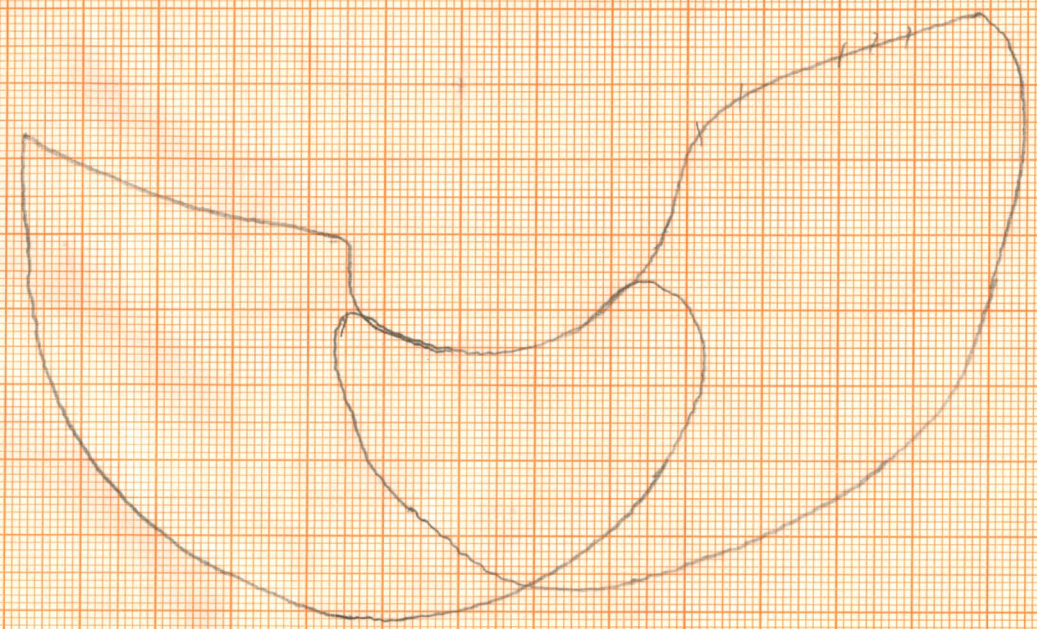


Z = -50 cm

Max ROM Unsuited

R

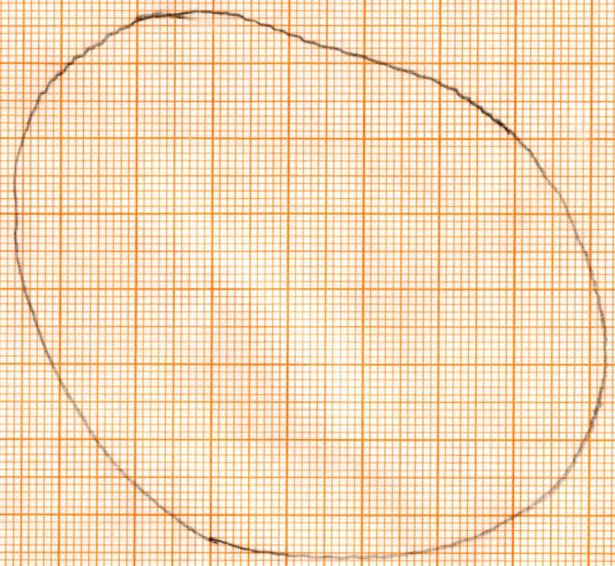
L

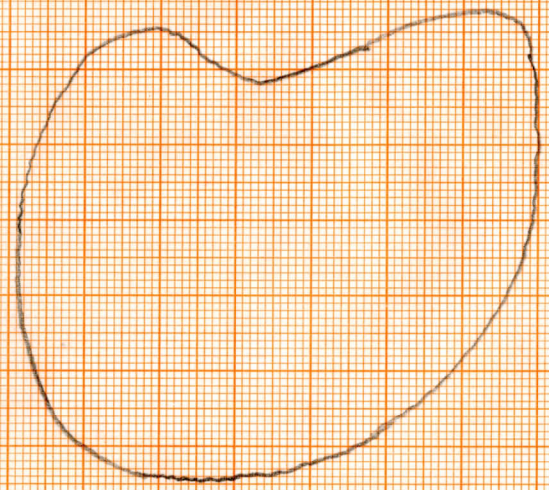


Z ≈ 65 cm

Max ROM Unsuited

P



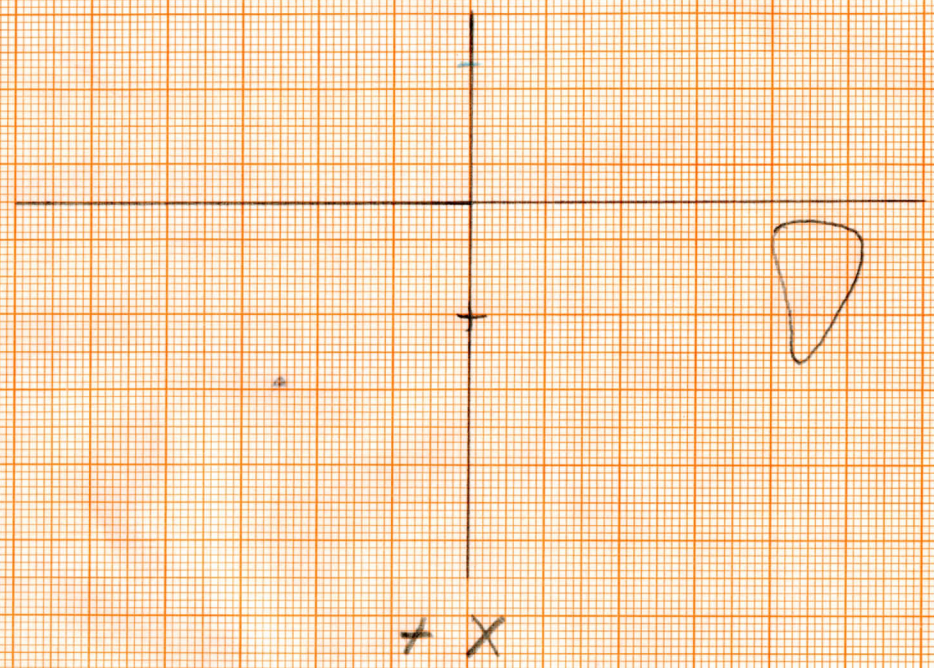


L

Z = -50 cm. (-60)

Max ROM Ⓡ & Ⓛ cm. ——

Funct ROM - - - - -




NB - no points reached on Ⓡ side at this level and no points on either side at -60 cm.

STS Suit 4 PSI Buchli

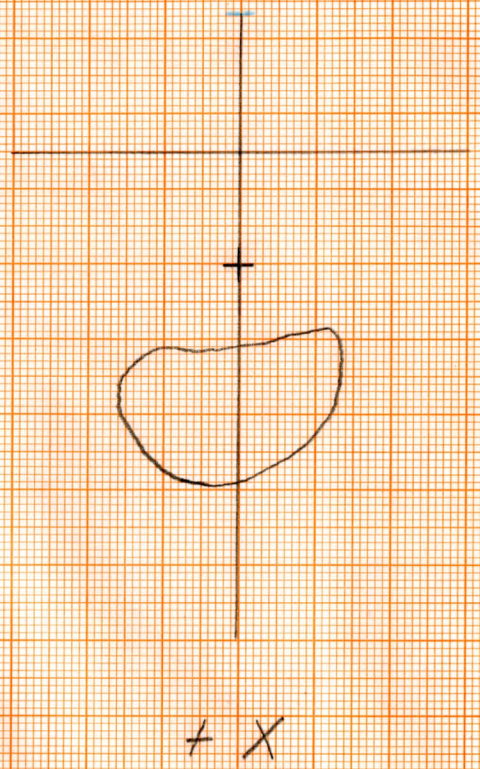
Functional two hand reach

X ref. is midline Scyes, Y is mid line

Each sm. div. = 1 cm W.S. 3.9.79

Z = -10 -60

Twohand Task Funct ROM

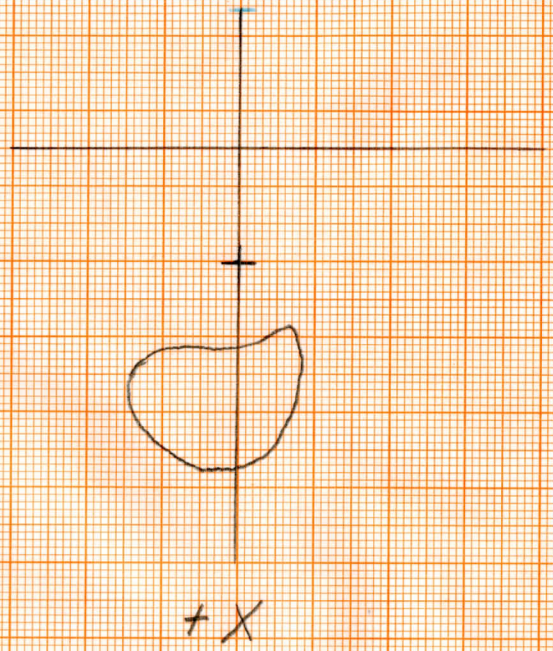


Z = -20 cm -70

Twohand Task Funct. ROM

R

L

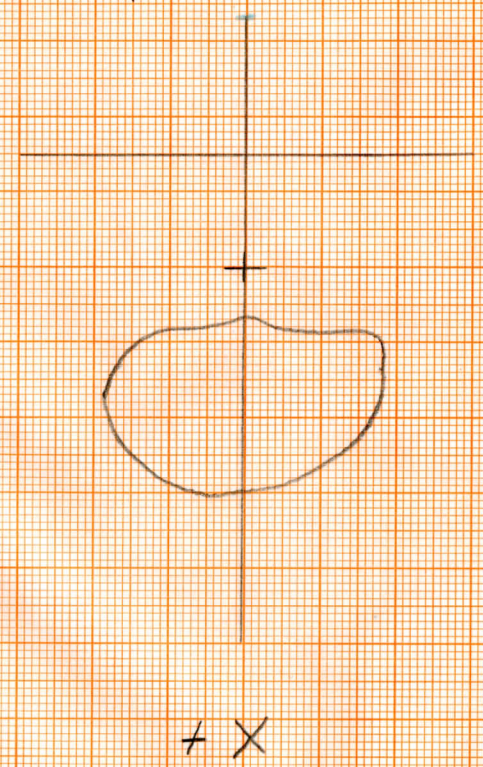


+X

NB - no points at -30 cm level

Z = + 0 cm - [illegible]

Twohand Task Funct ROM

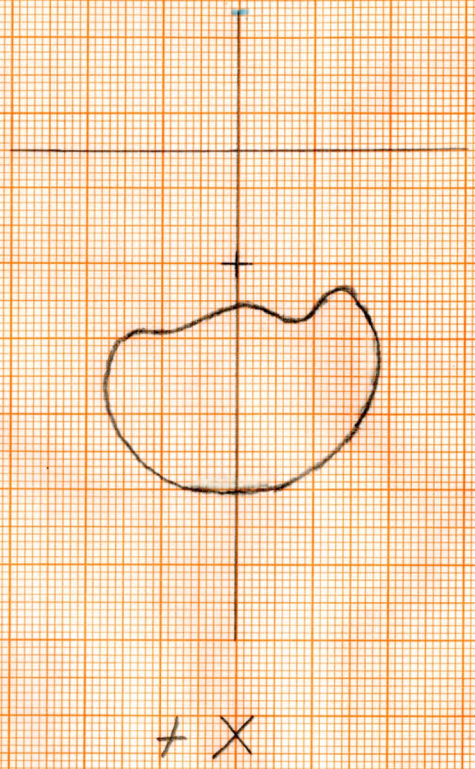


I = + 10 -40

Twohand Task Funct ROM

R

L



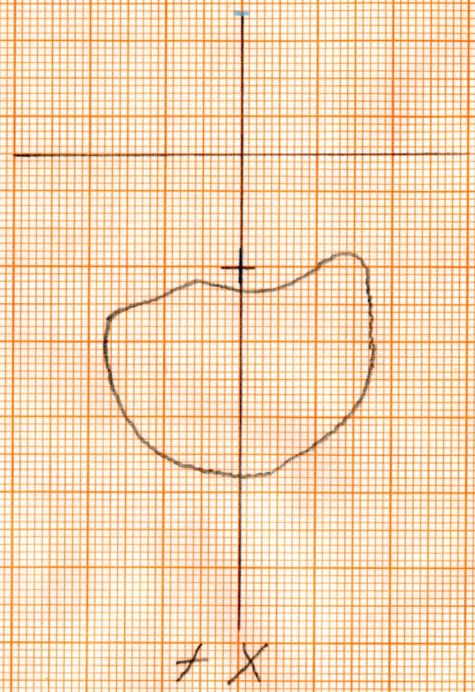
+ X

Z = +20cm

Twohand Task Funct ROM

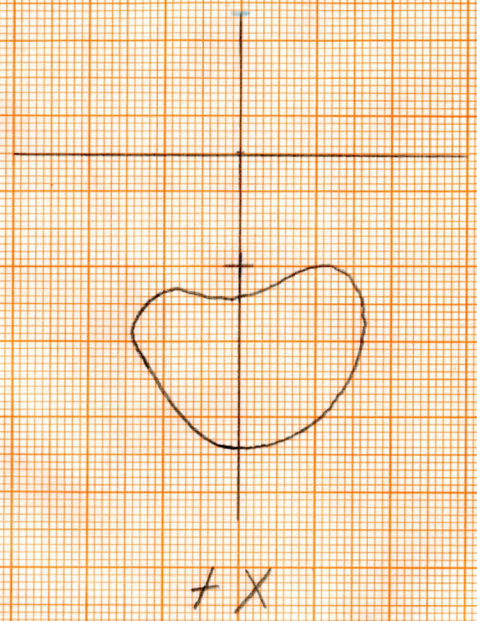
R

L



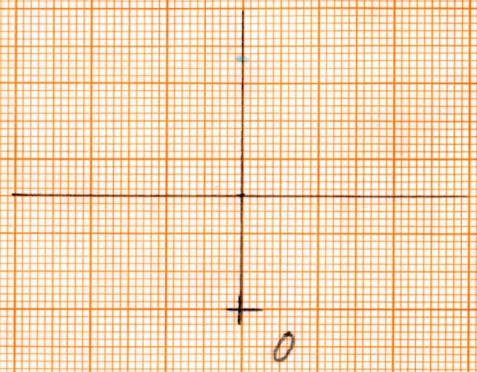
Z = +30 cm - 20

Two hand Task Funct ROM



Z = +40 cm -10

Two Hand Task Functional ROM




+X

NB - no points above this level

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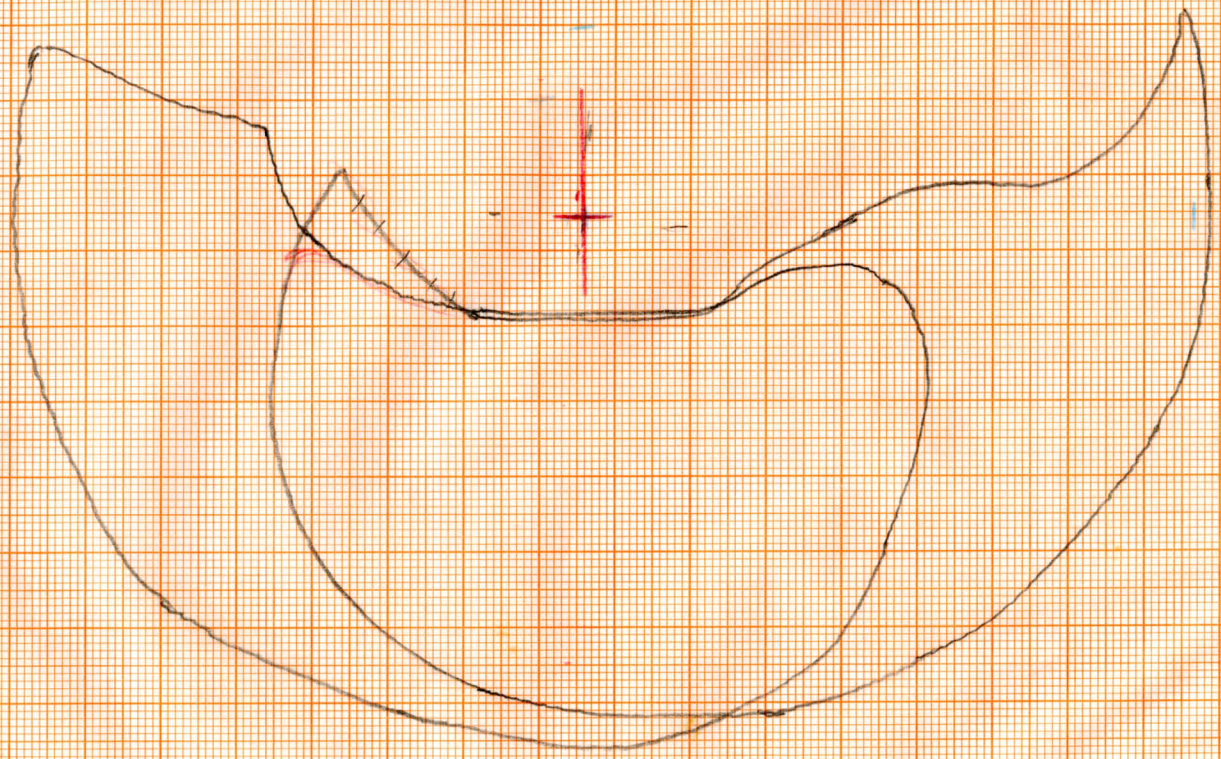
I ≈ 0 cm.

Max ROM Unsuited

R

L



B

# Maxim. Reach, S.M., ® Arm in A7 Suit, 3.8 PSI

each sm. div. = 1 cm

W.T. 4.9.79