CE56

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WITH SKYLAB, MASS MEASUREMENT IN SPACE FLIGHT

BECAME A MORE OR LESS ROUTINE OPERATION. THIS WAS NOT

ALWAYS TRUE. INDEED THIS WAS THE FIRST EXAMPLE OF SUCH

MEASUREMENT. ONE OF THE FIRST SIGNIFICANT AND ~~CONSISTENT~~ noted

CHANGES SEEN IN CREWMEN RETURNING FROM SPACE FLIGHT

WAS A WEIGHT LOSS WHICH SOMETIME SEEMED TO BE A

There were other associated

FUNCTION OF FLIGHT DURATION ~~WITH~~ MANY VARIABLES, however-

This also made it possible to make in flight measurements

~~THERE WERE~~ SEVERAL THEORIES CONCERNING THE MECHANISM

OF THESE LOSSES INCLUDING: (1) A SHIFT OF FLUIDS CEPHLAD

AFTER REMOVAL OF GRAVITATIONAL FORCES WITH DUMPING

OF THIS APPARENTLY EXCESS FLUID THROUGH DIURESIS;

(2) FLUID LOSS THROUGH SWEATING FROM INCREASED

ENVIRONMENTAL TEMPERATURES AND OTHER STRESSES;

(3) INADEQUATE FLUID OR FOOD INTAKE.

IN 1965, IT WAS OBVIOUS THAT ~~DAILY~~ INFLIGHT ~~CREW~~ BODY -

(AND INTAKE-OUTPUT)

of specimen and their intake-output
QUANTITATIVE LONG-TERM MASS MEASUREMENTS WOULD BE REQUIRED
study
TO SUBSTANTIATE THESE CHANGES AND DETERMINE WHICH
Aerospace
MECHANISMS WERE RESPONSIBLE. AT THE AIR FORCE'S MEDICAL
DIVISION, WE CONCLUDED THAT DEVELOPMENT OF A NON-
GRAVIMETRIC MASS MEASURING DEVICE WAS OF FIRST PRIORITY
TO INVESTIGATION OF THIS FUNDAMENTAL PROBLEM, AND
I BEGAN SUCH DEVELOPMENT. BY 1966 A DEVICE FOR MEASURING
MASS OF SPECIMENS OVER THE RANGE OF 25 GRAMS TO 1 KILOGRAM
AND A LARGER ONE COVERING THE RANGE OF 1/2 TO 100 KILOGRAMS
WERE COMPLETED. SKYLAB HAS BEEN THE FIRST OPPORTUNITY
TO DEMONSTRATE THEIR PERFORMANCE IN FLIGHT. SINCE
THE METHOD OF MASS MEASUREMENT USED IS A FUNDAMENTAL
DEPARTURE FROM WEIGHING MACHINES, THE TECHNIQUE WILL
BE DESCRIBED.

MAN HAS BEEN USING THE GRAVIMETRIC BALANCE OR SCALES

(FOR AT LEAST)

FOR AT LEAST 5,000 YEARS. IT IS SUCH A SIMPLE, EFFICIENT, AND ACCURATE METHOD THAT NO ALTERNATIVE DEVICES WERE AVAILABLE OR NEEDED. IT IS ONLY WHEN ONE ATTEMPTS TO DEVELOP AN ALTERNATIVE TO WEIGHING THAT THE METHOD IS TRULY APPRECIATED. THE ONLY PRACTICAL ALTERNATIVE TO GRAVIMETRIC ATTRACTION OF MASS IS SOME MEASURE OF ITS INERTIAL PROPERTY. IN 1965, THE METHOD THAT WAS CHOSEN, A METHOD HEAVILY BIASED BY SIZE AND WEIGHT REQUIREMENTS AS WELL AS BY MY PREVIOUS ELECTRONIC EXPERIENCE, WAS A MASS DEPENDENT TRANSLATIONAL MECHANICAL OSCILLATOR.

SLIDE 1 IS A SCHEMATIC OF THE METHOD USED. A SAMPLE MASS IS CONSTRAINED TO LINEAR MOTION BETWEEN TWO SPRINGS. IF THE MASS IS DISPLACED FROM ITS REST OR STABLE POSITION AND RELEASED, IT WILL UNDERGO VIRTUALLY

(UNDAMPED NATURAL)

UNDAMPED NATURAL OSCILLATION WHOSE FREQUENCY IS A FUNCTION ONLY OF THE MASS AND SPRING CONSTANTS. AN ELECTRO-OPTICAL DETECTOR AND COUNTER TIMES EACH CROSSING OF THE ZERO DISPLACEMENT POINT ALLOWING ACCURATE MEASUREMENT OF THE PERIOD OF OSCILLATION. BY CALIBRATING THE DEVICE WITH A SERIES OF KNOWN MASSES, THE MASS OF AN UNKNOWN SAMPLE CAN BE DETERMINED FROM ITS PERIOD OF OSCILLATION.

SUCH A TECHNIQUE ALLOWS REASONABLE ACCURACIES WITH SOLID MASSES -- FOR EXAMPLE, IT IS NOT PARTICULARLY DIFFICULT TO OBTAIN .01% OR MORE. CONVERSELY, THIS TECHNIQUE HAS SEVERAL INHERENT LIMITATIONS. ANY MOTION (JITTER) OF THE SUPPORTING MECHANISM OR OF THE SPECIMEN WILL PRODUCE ERRORS. ANY NON-RIGIDITY OF SPECIMEN (SLOSH) WHICH ALLOWS SECONDARY OSCILLATIONS NEAR THE PRIMARY

(FREQUENCY)

FREQUENCY WILL PRODUCE ERRORS ALSO. THUS, MEASUREMENT OF ITEMS SUCH AS LIQUIDS AND OF THE HUMAN BODY REQUIRE SPECIAL ARRANGEMENT.

ALTHOUGH EXISTING VIBRATION STUDIES OF THE HUMAN BODY SHOW THAT IT BEHAVES AS A SINGLE RIGID MASS BELOW ONE CYCLE PER SECOND, THIS PROVED NOT TO BE THE CASE. THE FREQUENCY OF OSCILLATION HAD TO BE LOWERED TO LESS THAN ONE HALF CYCLE SECOND, AND THE BODY FOLDED INTO THE MOST RIGID CONFIGURATION POSSIBLE.

MOTION PICTURE

I ~~would~~ will [illegible] S. L. [illegible] film made [illegible] demonstrating [illegible]

EXPERIMENTS MO74/172 WERE ALSO INTENDED TO EXPLORE THE COMPLETE ENVELOPE OF PERFORMANCE OF THIS METHOD, BUT SINCE ONLY THE INVESTIGATOR HAS DISPLAYED ANY INTEREST IN THIS ASPECT IT WILL NOT BE MENTIONED EXCEPT TO SAY THAT ACCURACIES OBTAINED ARE MORE THAN ADEQUATE FOR ANY CURRENT MEDICAL INVESTIGATIONS -- A FEW GRAMS FOR FOOD RESIDUE AND LESS THAN ~~1/4 POUND~~ ± 50 gms. REPEATABILITY FOR BODY MASS WITH ABSOLUTE BODY MASS BETWEEN +. 25 TO ~~+1.0~~ + 100 to + 450 POUND, PROBABLY CLOSER TO THE LOWER FIGURE.

OPERATION ON SKYLAB HAS BEEN MORE OR LESS ROUTINE. THERE WAS A GAP OF THE FIRST FEW DAYS ON SKYLAB-2 DURING VEHICLE REPAIRS. VIRTUALLY NO UNEATEN FOOD HAS BEEN LEFT TO MEASURE. ~~ACCURATE~~ No VOMITUS SAMPLES, ~~OF~~ on SL-2. THE ORDER OF 100 MILLIGRAM WERE PRODUCED ~~BY~~ ONE CREWMEMBER ON SL-3. ALL FECAL SAMPLES WERE ROUTINELY MEASURED BUT SHOWED LITTLE EXCEPT THE MARKED VARIATION

(IN HABITS OF)

IN HABITS OF INDIVIDUAL CREWMEN. OTHER MASS MEASUREMENTS HAVE BEEN ROUTINELY MADE IN SUPPORT OF SPACECRAFT OPERATIONS INCLUDING URINE POOLS AND THE AMOUNT OF COOLANT FLUID ADDED TO THE REFRIGERANT SYSTEM.

BODY MASSES HAVE BEEN THE MOST REVEALING. AS A BASELINE SUCH MASSES WERE MADE GRAVIMETRICALLY ON SMEAT -- THE GROUND-BASED CHAMBER SIMULATION.

GRAPHS OF THE CREWMEN'S BODY WEIGHTS WHILE ON THE SKYLAB DIET ARE SHOWN HERE. (SLIDES ____, ____, AND ____.)

NEXT ARE SHOWN THE RESULTS FROM SL-2. THE DATA HAS BEEN SMOOTHED BY PLOTTING A 3-DAY SLIDING AVERAGE. WEIGHTS ON BEGINNING THE DIET, ON LAUNCH, AND ON RECOVERY ARE HIGHLIGHTED. THESE POINTS ARE GRAVIMETRIC WEIGHTS. SL-2 CDR LOSS CURVE IS TYPICAL OF ALL THREE CREWMEN ON THIS MISSION. THERE WAS A SMALL BUT DEFINITE LOSS DURING THE CONTROL PERIOD (I.E., WHILE ON THE SKYLAB DIET AND

(IN QUARANTINE).)

IN QUARANTINE). AFTER LAUNCH THIS RATE OF INCREASE ACCELERATED BUT REMAINED MORE OR LESS CONSTANT EXCEPT FOR SHARP DROPS ASSOCIATED WITH EVA'S. FOLLOWING RECOVERY THERE WAS A RAPID INCREASE, ACCOMPANIED BY AN OVERSHOOT WHICH, ALTHOUGH NOT SHOWN HERE, PLATEAUED TO A VALUE SOME TWO PLUS POUNDS BELOW LAUNCH WEIGHT. (SLIDE ____) THE PLT'S CURVE HAS THE SAME GENERAL SHAPE WITHOUT THE POSTFLIGHT OVERSHOOT WHILE THE SPT'S CURVE IS MORE VARIABLE.

THERE WERE MARKED DIFFERENCES IN SL-2 CURVES IN TWO OF THE SL-3 CREWMEN -- CDR AND PLT. (SLIDE ____) AFTER THE FIRST DAY OF THE STABILIZATION PERIOD THERE WAS NO LOSS OR POSSIBLY A SLIGHT GAIN. INFLIGHT THERE WAS AN INITIAL LOSS FOLLOWED BY A LONG STABLE PERIOD UNTIL JUST PRIOR TO THE END OF THE MISSION WHEN A RAPID RATE OF LOSS (SLIDE ____) OCCURRED. THE SPT HAD A SLIGHT LOSS

(DURING THE)

DURING THE CONTROL PERIOD, A SLOW LOSS WHICH CONTINUED INFLIGHT AFTER A MARKED DECREMENT OVER THE FIRST FEW DAYS. AFTER RECOVERY WE SEE THE TYPICAL RAPID INCREASE FOLLOWED BY A PLATEAU OR INFLECTION.

THERE IS ONE OBVIOUS PATTERN OF LOSS HERE WHICH WAS ALSO SEEN IN THE CONTROL STUDY. CONVERSELY, THERE ARE MORE SUBTLE PATTERNS, ESPECIALLY THE RAPID SHIFTS WHICH MUST BE INTERPRETED IN CONJUNCTION WITH A GREAT DEAL OF OTHER DATA, SOME OF WHICH UNFORTUNATELY DOESN'T EXIST. THIS ADDITIONAL DATA SHOULD INCLUDE INTAKE OUTPUT STUDIES, PHYSICAL CONDITION OF THE INDIVIDUAL CREWMEN, AMOUNT OF EXERCISE, LEAN BODY AND FAT STUDIES, ANTHROPOMETRIC MEASUREMENTS, AND MUSCLE FUNCTION.

FOR EXAMPLE, IT IS VERY TEMPTING TO POSTULATE THAT THE RAPID CHANGES SEEN FOR THE FIRST FEW DAYS AFTER ORBITAL INSERTION AND AFTER RECOVERY ARE FLUID SHIFTS.

(HOWEVER, )

HOWEVER, ON SL-3/4, WE HAVE TWO CREWMEMBERS WHO EXPERIENCED NORMAL CONDITIONS ON EXPOSURE TO WEIGHTLESSNESS (I. E., THEY DID NOT HAVE NAUSEA, ANOREXIA, OR EXCESS ENVIRONMENTAL TEMPERATURES). THERE WAS NO SUCH RAPID LOSS OF WEIGHT SEEN. CONVERSELY, THE CREWMAN WHO HAD NAUSEA SHOWED A "TYPICAL" RAPID LOSS OF A FEW POUNDS FOR THE FIRST FEW DAYS. WE ARE ATTEMPTING A SERIES OF ADDED STUDIES ON SL-4 TO ATTEMPT TO DOCUMENT ANY FLUID SHIFTS.

AS OFTEN HAPPENS, THE INFLIGHT MASS MEASUREMENT DATA FROM SKYLAB DEMONSTRATED COMPLEXITIES AND RAISED QUESTIONS NOT ANTICIPATED PRIOR TO SKYLAB. MOST OF THE LOSS WILL BE EXPLAINED BY THESE AND COROLLARY MEASUREMENTS. EQUALLY IMPORTANT ATTENTION WILL BE PROPERLY FOCUSED ON THE REMAINING UNKNOWNS SUCH THAT PROPER INVESTIGATION MAY BE IMPLEMENTED.

(FINALLY, )

FINALLY, THERE IS THE QUESTION OF MASS MEASUREMENT ITSELF ON FUTURE MISSIONS -- MISSIONS THAT MAY NOT HAVE ALMOST UNLIMITED RESOURCES. THE MASS MEASUREMENT DEVICES FLOWN ON SKYLAB, ARE RELATIVELY CRUDE, OBSOLESCENT, AND EXPENSIVE. IN THE INTERVENING 7 YEARS SINCE THEIR DESIGN, I HAVE DEVELOPED A SERIES OF SMALLER, SIMPLER, AND CHEAPER ALTERNATIVES -- SOME OF WHICH ARE ABOUT TO BE ZERO-G TESTED WHICH SHOULD ALLOW MASS MEASUREMENTS ON VIRTUALLY ANY OBJECT IN ALMOST ANY SPACECRAFT.

THANK YOU.