"NINE MONTH" PLAN (FOR FLIGHT EXERCISE GEAR)
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1. BACKGROUND-

It was recognized from the earliest days of Space Flight that exercise could play a significant role in successful operations and this has been confirmed by both U.S. and Russian programs. Space Station (S.S.) has a significant amount of exercise and hardware as an integral part of its program. EDO experience was planned as a validation of the protocols and apparatus for S.S. Currently the only exercise hardware available for an active EDO program is an outmoded (1974) treadmill (T.M.) A systems PDR for S.S. exercises is due in 1-2 months and a PDR in a year and the only flight experience and hardware is Skylab and the STS T.M.

An exercise program and hardware for space was started for the USAF MOL in 1966 and has been continued to the present. In addition to investigations and development of a 'Total Body' Exerciser device for MOL, this program included studies and design of cycle ergometers followed by a prototype Apollo egrometer, commercial treadmills and metabolic gas analyzers, exercise studies and devices for Skylab, development and test of the Shuttle T.M., a horizontal 1g T.M. device, rowing machines, synthetic force generator, egrometer and many other relevant studies and devices. As a result of this experience and extensive theoretical studies, an exercise protocol for extended flight was established and supporting hardware designed in 1987.

In 1987, modest funding was obtained to build part of the hardware to support this program. This effort was delayed until 1989 but has now produced:

1. A 1g. prototype T.M. and subject force unit for EDO/S.S.

2. A flight isometric dynamometer.

3. A flight rowing machine.

Additional items to be delivered shortly include:

4. A flight istonice load unit for heavy strength exercise.

5. A prototype 'universal' exercise device for trunk and upper body which also includes isometric, isotonic and isokinetic egrometry.

This apparatus was delivered on budget ($225k) and except for government induced delays, on time. As a result of this effort and experience derived from the hardware, we can state with great confidence that it is now possible to have delivered, ready for flight, or in some cases to have flight tested, all of the exercise flight hardware prototypes for needed for S.S., in 9 months, and for modest cost. Unfortunately such an effort requires considerable NASA support which based on the past year's experience, is not currently available. If for example I were to try to produce just the treadmill under the present circumstance at least two years would be required. A number of changes in organization and procedures will be required to support the proposed effort.

A proposal that describes a program to produce and test the hardware with the resources necessary to support this effort follow.

2.Plan, general overview:

Hardware production; deliveries quoted are from signing of contract. This would be a continuation of the current contractor effort and would produce or test the following items. Cost and delivery schedule are in Tables 1 & 2.

1. A treadmill compatible with EDO operations with the basic features required for S.S. This will include a low noise belt of adequate

dimensions, an improved subject weight equivalent load, read-out and signals for subject equivalent weight, speed and equivalent grade. Speeds of 2-6 mph. at equivalent grade of $\leq$ 10% and speeds of 2-6 mph. and at grades of 0% with optional motor drive. This is the basic exercise for leg muscle-sketal and cardio respiratory (aerobic) maintenance.

2. A universal egrometer/dynamometer which will produce weight equivalent loads over the range of 10-250 lbs. and which will measure forces (strength) to 350 lbs. in isotonic, isometric or isokinetic modes. A series of bars and pulleys, cables and handles will allow virtually any of the current 1 g. weight exercises. This is primarily for trunk and torso musculoskeletal maintenance.

3. A bicycle egrometer, 0-350 watts input, 50-100 rpm with read-out and signals for velocity and power. A constant load arrangement is optional. This is a purely aerobic exercise of interest to researchers or in case of some disability. IP 4. A rowing machine with performance equivalent to good 1g design i.e. with correct inertia and resistance, which will operate over 10-50 strokes min. with average inputs to 300 watts. This is an optional exercise which cannot replace items 1 & 2 but which allows a diversion. It produces poor musculoskeletal loads in leg and fair loads in back and arms with good to excellent cardiorespiratory (aerobic) loads.

5. Other exercisers could be produced in the same time frame eg. the climber is frequently advocated as an exerciser and it has roughly the same limitations and strengths as the rowing machine.

3. Design and production:

Results to date have depended upon a unique collaboration of the author and a talented individual who also has unique production facilities eg. W.

Thornton and H. Whitmore with Whitmore Enterprises. This relation must be maintained for any hope of success and especially in this time frame.

There is an unfortunate idea extant that by simply writing adequate specifications a contract will produce working hardware. This is simply not the case and even with a tightly specified fixed price contract to Whitmore a great deal of technical interaction and development must go on to get a usable product at this stage of totally new items. The contract must continue with Whitmore under the direction of Thornton to take advantage of unique knowledge and experience.

A current contract for exercise gear with option for extension is operative but the official time to extend this option has passed. Whether a further extension is possible I do not know.

In summary the present Thornton-Whitmore effort should be extended to produce equipment described.

4. TESTING/CERTIFICATION FLIGHT VALIDATION:

An essential part of such a program is both ground performance and certification testing and finally flight testing. Adequate technical facilities must be available which include a variety of force/torque, displacement, velocity, frequency response and other measurements as well as simple electronic and mechanical fabrication facilities. As part of the current program we have established such a lab at the Mac/Dac (MDC) Checs facility which now has unique capabilities in this area. Free and priority access to this lab must be available. Lack of such access has been a significant problem in the past. Again control of the testing must be under the direction of Thornton.

Much of the testing will involve human subjects and weeks to

months of time were lost to the biopolitical morass involving the use of humans to do what the subjects normally do without any control every day; walk, jog and lift weights at modest effort. The problem was finally circumvented by going to South Shore Harbor Fitness Center which also does professional in-house investigations. They did the testing in a most safe, efficient and effective way at very modest cost. It is essential that such technical and human test facilities be routinely available.

The final test is flight. Experience with the current treadmill is dramatic proof that any exercise device must be tested for its characteristics and rules for its use must be generated from flight experience before it is ready for routine use i.e. the necessary DTO must be performed and performance and rules for use documented. This again runs into a biopolitical closed shop. Some means of a) preparing the necessary paper work, etc. and b) getting the test done in an expeditions fashion must be available eg flight hardware from the present development program has been available for months and will not be tested for a year. Some priority must be established.

Certification:

An organization exists to do this and there is reason to believe that given priority they could adequately certify this hardware.

5. SCHEDULE:

Table 1.A-D, shows a continuation of the existing program and its proposed extension. The unknown is time to let a contract. This was shown as two months. With adequate administrative support the time to prepare contract specifications is an estimated two weeks.

TREADMILL:

Depending upon utilization, 1 or 2 flights will be required for the DTO to technically evaluate this item with another 2 months for preparation of the report and users manual.

The optional motor drive will allow operation at zero equivalent grade and might require up to an additional 3 months for deliver. DTO testing would also be required.

UNIVERSAL EGROMETER:

A second generation prototype will be delivered in August and require 2-3 months testing, however, sufficient information exists to write a contract for a flight prototype. This is the most complex item and needs considerable flight experience to allow fine tuning for S.S.

BICYCLE EGROMETER:

Is a very simple item which uses the same proven load mechanism as the rowing machine. It can be delivered and flight tested in the 9 month period. If a constant load feature is desired this may be added but would extend delivery 3 months and increase cost.

ROWING MACHINE:

Prototype Flight hardware has been delivered and is in certification process. There is a tentative plan to fly it on a DTO next year. A second unit with instrumentation to measure work and cycle rate as well as the velocity would be in order. This is a relatively low cost item and would also augment the existing single unit, hence it was included.

6. <u>COSTS and DELIVERY</u>:

Estimated manufacturing costs are shown in Table 2. Other overhead costs in JSC were not available to me.

7. SUPPORT AND ORGANIZATION:

The director of this effort must have the authority and not just responsibility for this effort. He must also have the following committed support.

1. Administrative support equal to a 1/2 time secretary where certain correspondence could be immediately dealt with, maintenance of a documentation/communication file accomplished and aid in phone/FAX communication given, etc. The existing departmental arrangement does not work.

2. A subsystems manager that could interface with the various elements such as SR & QA, buyer, etc.

3. A person or person who can provide up to full time aid in aid in preparation of DTO, DSO, reports, etc. This need not be the same individual for DTO/DSO work is different from reports and there will be varying demands on these.

4. The equivalent of a full time person to follow and aid in the various certification tests, SR & QA documentation, pre-flight interface, post flight equipment recovery, etc.

Other:

Also essential is free access to all elements, plans, tests, etc. which affect or are affected by this work. Major problems, often unrecognized, have arisen from the disorganized, uncoordinated and uninformed use of the STS T.M. To be effective this new hardware must be designed to meet basic physiological needs, not vice versa, and this has been done. Conversely it is essential for the designer to know if there are additional features required by others. Equally important other users must know what the capabilities

and limitations of the apparatus. So far there has been an iron curtain between the designer/developer and both the professional world and especially locals who are working the same problem e.g. I have not been able to get information much less participate in debriefings on the use of the existing T.M. At least once I was told this was confidential medical data--which is widely distributed to non professional support elements, etc. yet kept from an astronaut, physician and only person who really understands the device being used. A normally professional environment must be established.

An essential practice must be instituted for this hardware,as is done in all other flight hardware including the Shuttle. Performance must be verified under conditions of actual use and rules and limitations established for such usage. The only way to do this currently is via DTO's which will then allow performance specs. and guidelines to be established. After that the users must be responsible for proper utilization. In terms of those who fly, flight tests must be performed, dash ones written and restrictions respected. This is not currently the case.

Inherent in this plan is an orderly, achievable and verifiable progression from current concept through flight test which will produce hardware of known performance and documented rules for usage. Milestones are inherent and will be closely watched.

TABLE 1 A
TREADMILL (MKII)

Event	1989									1990											1991								
	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J?A	S	O	N	D	J	F	M	A	M	J	J	A	S
ADMIN. APPROV.	X						CURRENT CONTRACT									C													
CONTR. SIGNED						X										O													
1G PROTO DELIV.										X						N													
TESTING										X----------						T													
																R													
																A													
CONTRACT:							NEW OR EXTENDED CONTRACT									C													
																N													
																E													
																G													
																O													
SUBMISSION															X	T													
																I													
SIGNED																A	X												
																T													
ITEM. DELIV																I									X				
																O													
CERTIFICATION																N										X			
FLIGHT DTO																											X		
DTO SUBMITTED																				X									
REPORT																													X

TABLE 1 B
UNIVERSAL ERGOMETER

Event	1989									1990											1991								
	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J?A	S	O	N	D	J	F	M	A	M	J	J	A	S
ADMIN. APPROV.	X						CURRENT CONTRACT									C													
CONTR. SIGNED						X										O													
1G PROTO. DELIV																N	X												
TESTING																T	-------		X										
																R													
																A													
																C													
																T													
																N													
																E													
CONTRACT:							NEW OR EXTENDED CONTRACT									G													
SUBMISSION															X	O													
SIGNED																T	X												
ITEM. DELIV																I									X				
CERTIFICATION																A									-----	X			
FLIGHT DTO																T											X		
DTO SUBM.																I				X									
REPORT																O													X
																N													

TABLE 1 C
BICYCLE ERGOMETER

Event	1989									1990											1991								
	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J?A	S	O	N	D	J	F	M	A	M	J	J	A	S
ADMIN. APPROV.							CURRENT CONTRACT									CONTRACT NEGOTIATION													
CONTR. SIGNED																													
CONTRACT:							NEW OR EXTENDED CONTRACT																						
SUBMISSION																X													
SIGNED																	X												
ITEM DELV.																				X									
CERTIFICATION																					X								
FLIGHT DTO																						X							
DTO SUBM.																			X										
REPORT																									X				

TABLE 1 D
ROWING MACHINE

Event	1989									1990											1991								
	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J?A	S	O	N	D	J	F	M	A	M	J	J	A	S
ADMIN. APPROV.	X						CURRENT CONTRACT																						
CONTR. SIGNED						X																							
FLT. HDW. DEL															X														
CERT.																	X												
DTO SUBM															X														
FLT. DTO'S (NOT SCHED)																		X											
REPORT																				X									
CONTRACT:							NEW OR EXTENDED CONTRACT																							
SUBMITTED																X													
SIGNED																	X												
2' FLT. ITEM																						X							
CERTIFICATION																								X					
DTO SUBM.															X														

CONTRACT NEGOTIATION

TABLE 2 HARDWARE COSTS AND DELIVERY

1. Treadmill- subject driven with extended tread surface, reduced noise (70 dBA), speeds 2-6+ mph at equivalent grade of ≤ 10% with an 80 kg. subject. Integral subject weight equivalent load of 100-200 lb, instrumentation to; display or record speed, equivalent subject weight and grade and an approximation of foot ground forces. Total weight ≤130#, flight prototype.

DELIVERY: 9 Months COSTS: $350K

A. Optional motor drive for above will allow adjustment of equivalent elevation down to and including zero degree elevation and speeds to 8 mph. zero Power- ≤300 watts power max.

DELIVERY: 12 Months COST: $100K

2. Egrometer Dynamometer- will produce external and body weight equivalent forces of 10-250 - lb. thru coupling apparatus to subject (cables, handles, bars, etc.) which will allow the equivalent of most of the standard weight exercises including chins, squats etc. Differential eccentric-concentric loads may be programmed. In the force generating mode concentric velocities will be limited for safety. Indication and signals for recording forces and velocities will be provided. Average Power-100w Est. weight 75lb. The unit also functions as a dynamometer in isometric, isotonic and isokinetic modes at forces up to 350 lbs.

DELIVERY: 9 Months COSTS: $350K

3. Bicycle egrometer- Passive (unpowered) 0-350 watts at 50-100 rpm with read-out and signals for speed and power- subject restraint will be included- ≤30 lbs.- locker stowable.

DELIVERY: 4 Months COSTS: $60K

Table 2, cont'd.

A. An optional constant load appatus for above is available which can maintain above load range over the speed shown.

DELIVERY: 9 Months COSTS: $40K

4. Rowing Machine- Additional units of the existing machine wt. 27 lbs., locker stowable, input loads to 250 watts at cycle rates of 15-30 min. and with velocity indication and signals

DELIVERY: 2 Months COSTS: $20K

A. A unit with instrumentation for speed, power and force is available

DELIVERY: 6 Months COSTS: $50K

5. Other apparatus could be produced in the same time frame eg. a climber.

DELIVERY: COSTS: $100K

The above items will be constructed as flight hardware with documentation for DSO class equipment. Costs are estimates and exact costs will depend on specs.