Notes from Dr. Wm. Thornton
Received 22 July 1969

Subject: LAPA (Camp Pickett, Virginia)
RFQ DAAG07-69-Q-0036 - Physiological Telemetry System
DEL Quote No. Q-12293

Dear F.

The fol[illegible]g a[illegible]e my off the c[illegible]iff comments on the proposed telemetry project. This is a [illegible]utiful opportunity but don't try to do it without professional help. By all means supplement it with a good bibliography. Don't get the idea you can do all the real work in Phase I.

DEL is in an excellent position to tackle this not only for reasons you named but for others I'll point out. The one bothersome aspect is how pricing will be accomplished - it should be separate for Phase I and II/III - for what is done in II/III is dependent upon I but it will probably be lumped.

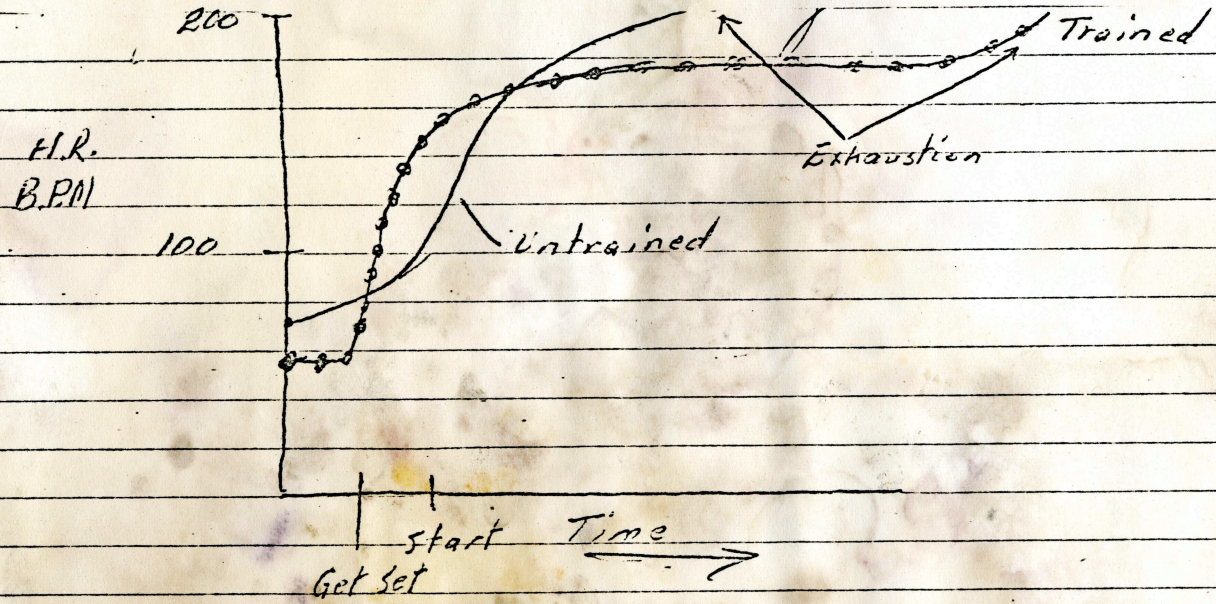
The important things are:

1. a system which works and fortunately this is simple for under the circumstances, the only two which can be seriously considered are core temp. and EKG. They obviously want 3 channels so have a spare channel for future development.
2. Off the shelf telemetry gear and already available gear GFE will do the job nicely.
3. DEL has some extras to offer in their recorder and an EKG computer.

Amplifying 1.

They have listed a number of indices which are discussed briefly.

Heart rate is undoubtedly the best studied index to date and there is a great volume of literature on the subject. The crucial point is that there is no universal value for all individuals. For example - some individuals can perform for considerable rates at over 200 B. P. M. while others, such as myself might not survive 180 B. P. M. Heart rate alone gives considerable insight into other factors such as 0_2 consumption in a given individual. Ken Cooper (1.) has made quite a study of this and should be contacted for details. It cannot be overstressed that psychic factors can greatly increase rates to and above abnormal levels. We found rates of above 185 for 15 minutes in students presenting their first cases, and in full professors presenting their 1000 th +. A curve below shows typical responses to heavy stress and as a long race.



(1.) Dr. Kenneth C. Cooper, Wilford Hall Hospital, San Antonio, Texas

The two individuals are assumed to have identical rate responses, one being a competitively trained runner and the other normal but untrained. The trained man's response roughly approximates a step function which typically shows its greatest amount of increase prior to the actual start, rapidly reaches a plateau and only increases slightly beyond this when he is pushed beyond his capacity. The untrained individual typically shows an always increasing rate at the same load. This means that good stability and resolution must be available from the rate meter (cardiotachometer) at high rates. Its scale must be linear. The success or failure of this project will hinge on how noise free the signal can be made and how well the cardiotachometer discriminates against the irreducible minimum of noise present in signal under vigorous work.

As regards the cardiotachometer, one could come up with an all digital unit using the computers listed but suspect it will be cheaper (do trade off in Phase I) to build a special purpose unit as shown below in the system diagram.

I strongly recommend that a clinical quality EKG be displayed and that at least one qualified observer be available for monitoring/consultation. These are sudden cardiac deaths in military training situations and although it has not been documented to my knowledge, the mechanism is almost certainly some type of arrythmia. This arrythmia or other EKG change almost certainly appears prior to the fatal event and as such monitoring would be invaluable. Further, the EKG will reflect marked chemical changes in the body which could well occur in the 8 hour period. One would not expect cardiac ischemias would be recorded.

Although this installation is obviously intended for use as a go/no-go monitor operated by minimally skilled personnel, the state of knowledge is not great enough to allow complete assurance that this can be accomplished. The large amount of additional data which can be obtained from EKG display/recording equipment without unduly complicating the system is more than justified. The additional gear would include a scope monitor and standard direct writer which could be switched into any channel for monitoring and selected recording. The recognition of arrythmias would require relatively little additional training for the monitors. A short record should be made of each subject before the run and this would be used as a standard of comparison during the run. In addition, if medical professional personnel are available by phone, a phone link/direct writer would make professional monitoring of suspected difficulties available at little additional cost. As the range experience and skill level increased, this professional monitoring would be less needed but might be invaluable at first.

Technical: Rate & EKG block.

See Page 5. for Figure 2.

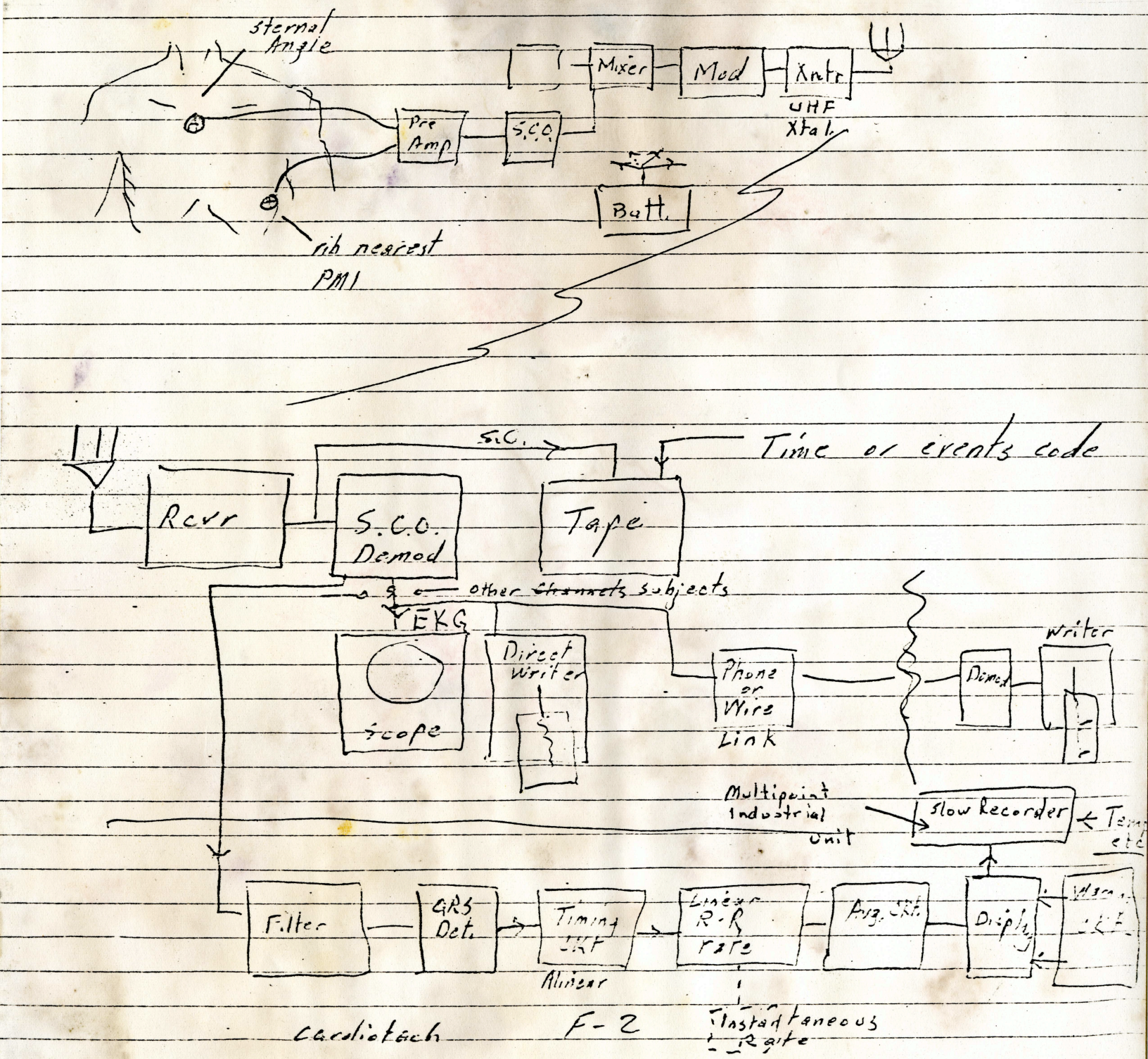

Sternal Angle
Mixer
Mod
Xmtr
UHF Xtal.
Pre Amp
S.C.O.
Batt.
rib nearest PMI
S.C.
Time or events code
Rcvr
S.C.O. Demod
Tape
other subjects
EKG
scope
Direct writer
Phone or Wire Link
Demod
writer
Multipoint Industrial unit
slow Recorder
Filter
QRS Det.
Timing SRT
Linear R-R rate
Avg. SRT
Display
Alinear
Instantaneous Rate
cardiotach
F-2

Figure 2.

See Figure 2. (Page 5). Lead (electrode) placement is critical. For rate only, two electrodes on the sternum would probably work reasonably well but for the maximum amount of information with a minimum of muscle and movement artifact, use the one shown. It has rough correspondence with V-6 of the standard system and since P, QRS and T complexes are prominent, it is excellent for arrythmia diagnosis and study. Approximately 85% of ischmias will be manifest in this lead. Skipping for the moment the T/M (telemetry) system, it is assumed that a short term data storage for each day's run would be desirable so a simple and inexpensive 1-2 track system could easily handle the information plus timing or code to allow correlation with other events. It is assumed that the tape would simply be reused unless some abnormality or unusual condition appeared in which case the tape could be saved for further study. This storage function is available in the existing recorders which appear to be digital units and would require some form of interface equipment. A single channel scope could be used to monitor any of three (or more subject) or if it were felt necessary a beam splitter could monitor 3 channels. Would not recommend the Avionics multi-beam unit but a Tek 564 storage unit with the alternate aplit screen write store arrangement I demonstrated some time ago. Avionics' direct writer could be switched into any channel to provide a graphic record of unusual events or for professional diagnosis in the case of emergencies (M. D.'s don't read scopes well). A commercial phone Data-Link would provide professional consultation should the need arise.

There are a million ways to design a cardio-tach but the essential features are a high sensitivity to noise, absence of operational adjustments, linearity and resolution, and a sliding average ckt with a time constant of greater than 10 seconds probably on the order of 20 - 305 with conventional adjustable rate limit/warning ckts - and possibly an instantaneous rate meter.

Heart rate and EKG will be the most valuable index both because of extensive studies available and because it is a reasonably good indicator if it is realized that each subject is different and has his own individual rate response. Applying fixed figures such as the 180 maximum mentioned will be dangerous and unsatisfactory. A slow recorder would give record of all subjects and responses.

In view of feasibility, core (rectal or ear canal) temperatures is the next best indicator. Surface temperatures are of little use in this situation. Rectal temperature would be better but this is really impractical under the planned activity. This leaves ear canal temperature which is considered by many to be equivalent to tympanic membrane temperature, (I don't necessarily concur), the best measure of core temperature. The drawback to this is that the ear must be well closed and this eliminates binaural hearing which may affect performance of the subject's combat tasks. The measurement and transmission of temperature data is extremely simple and it should simply be displayed on a stable long time constant (minute or more) digital meter covering the range of interest say 95° to 108° with an upper limit warning. There is some variability from subject to subject but much less so than with EKG and heart rate.

The above 3 items will provide an optimum approach but I suspect they actually want another item which will be discussed below. As a compromise I would provide the facilities in the T. M. system for inclusion of a third channel at any time desired.

The next most desirable index would be 0_2 consumption but the state of the art won't allow obtaining this measurement under the conditions. Respiratory rate and tidal volume would be considered valuable by some and I would

consider the data useful if it could be easily obtained. Someone, probably several, will suggest the use of the impedance pneumograph (someone may be impractical enough to suggest impedance cardiography), but the restrictions placed on the electrodes, the increased complexity of the T/M system and the complications of analysis plus the unreliability of the data would only compromise the entire system. If one had to attempt to get some measure of respiratory rate with some possible indication of relative volume, then a heated thermistor in the nasal air stream or a circumferential chest strain gauge could be used. The latter is preferable, would be relatively simple to T.M., but would be relatively clumsy to decipher and in my opinion wouldn't be worth the trouble. If there is insistence on a third parameter, then this would be it.

Blood and pulse pressure. - Under the conditions imposed, current indirect methods of measurement would be useless. Direct (invasion of artery) methods can't be considered. Blood and pulse pressure would indeed be a valuable index but even if some way were found to overcome the noise and movement artefacts in the acoustic or newer ultrasonic detection of B.P., the added complexities of inflation gear would make a combat situation T.M. unit impractical. The receiving station gear would also be greatly increased in complexity. NASA has played with indirect methods of picking up pulse pressure by means of a surface pressure transducer over an artery but this would be rendered useless by the activity of the subjects here.

Muscle Action Potential (EMG) is a potentially useful index when the necessary research has been done on the changes which occur in fatiguing. We, some years ago at the U.N.C. (2.), did the first work in T.M. EMG which was valuable for rehab studies but this work hasn't been extended to normals. The signal is

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(2.) J.F. Am. Phys. Theraphy Assoc. V43 #11 Nov. '63 P-787 - EMG T.M.

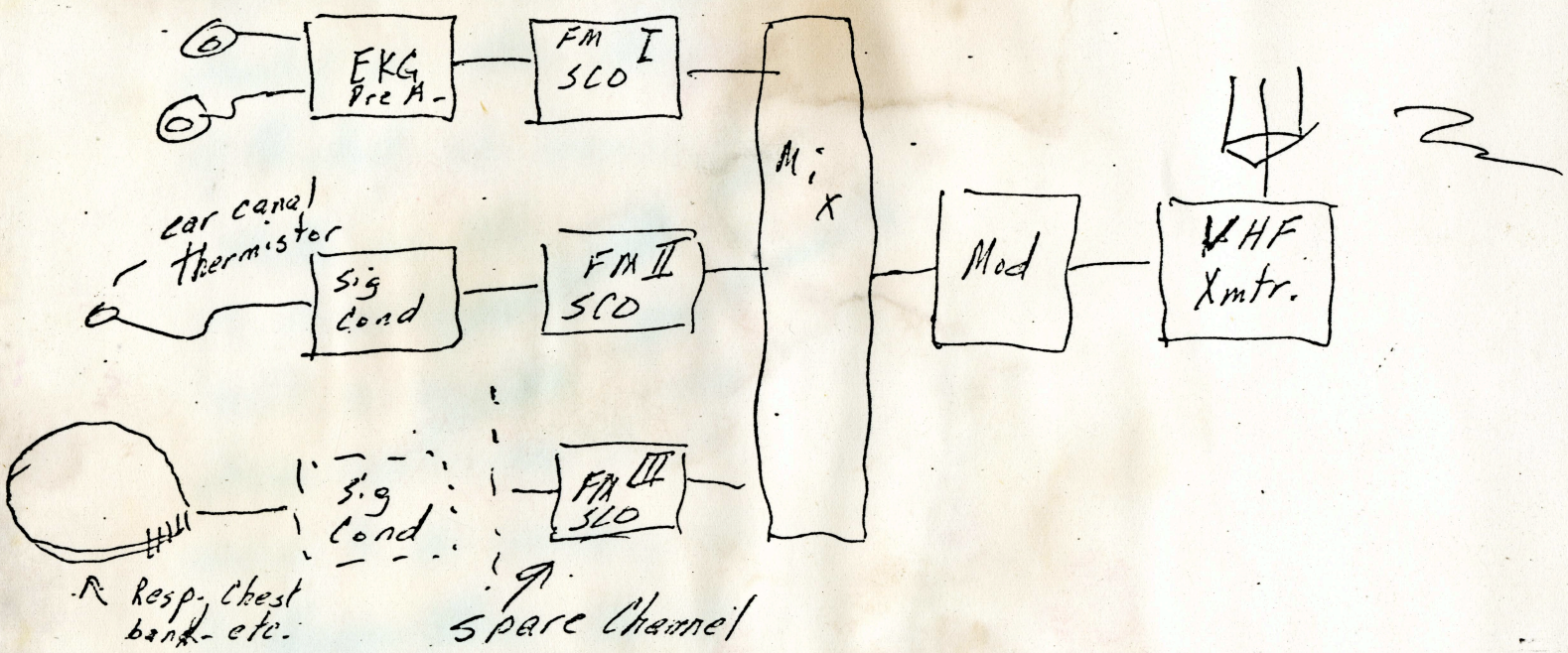
relatively easy to pick up with surface electrodes and is in a nice frequency range to handle single channel (10-10K. Hz) but for multiplexing uses a lot of spectrum. Once the signal is obtained, processing and display are complex compared to say the EKG. Unless a preliminary research program is done, EMG shouldn't be considered.

Other signals which may come up for discussion are EEG and an optical finger pulse pick up. Some of the more "Gung Ho" EEG researchers such as Adey at U. C. L. A. claim that the mental state of conscious, eyes open subjects can be obtained from machine analysis of multiple lead EEG's. This may be so but the computer required and ancillary gear restrict this to the research lab. The EEG signal itself could be easily obtained and T. M.

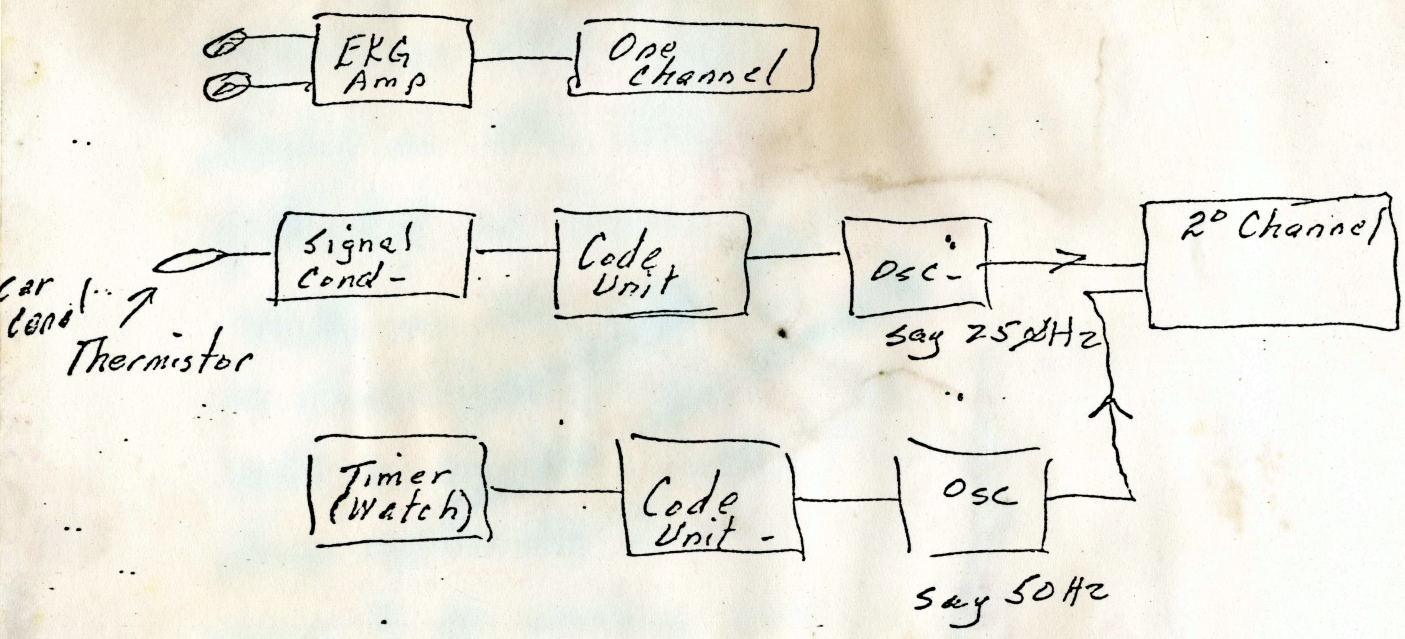
A so called finger pulse may be picked up relatively simply by a small transducer containing a small light and photo-electric pickup. This is supposed to give a measure of finger blood flow/quantity but it is not quantitative, is subject to variations and would mechanically interfere with the hand.

T. M. system. - This is easy and I'm sure Ray Cherry can give plenty of reasons why only radio T. M. should be considered. If I've interpreted the map correctly, a single omni antenna placed at the blue X would have a maximum range of 2500'. A 1/2 watt VHF transmitter should handle this easily and be compatible with the 4# weight limit. If terrain interferes or there are other problems, multiple receiving antennas/stations could be used. It might be worth picking up a coupld of VHF walkie-talkies and trotting over the range with them. Remember the transmitter isn't fixed.

The T. M. system can and should be picked up commercially in sub units with possible fabrication of the EKG preamps.



Del Mar Engineering Laboratories should stress their experience, photos, etc. with electrodes, EKG, T.M., recording, cardio-tach., etc. Although no one understood it, I sent an automatic EKG analyzer out when I was in Med School (3.) which I've tried to get Bruce to update and which would be most useful as a monitor of the EKG signal. In addition, they want remote recording facilities and the Holter apparatus can be nicely modified to do the job as below. STRESS THIS



Couldn't come with a professional consultant out there but a good possibility is Dr. Jere Mitchel, Southwestern University School of Medicine, Dallas, Texas. Don't try to use someone without specific experience in the art - don't get a cardiologist only for example. Don't use my name (I'd give the same help to anyone else) except literature reference or the like. Call for any questions.

Good luck

Bill

(3.) Published in New England Journal Medicine - also patent. (Bruce should have reference)