Certainly the most spectacular example of biomedical telemetry has been from American and Russian Space Flights. Although this has been a dramatic illustration of a technique, the actual technology involved, other than electrodes, has been relatively straight forward engineering using techniques only slightly modified from industrial designs.

FIGURE 1. There will or certainly should be a significant spin off from this effort. A problem which will be faced with 2^{o} generation space efforts, especially orbiting laboratory operations, will be the development of monitoring techniques. This problem will not only require development of new technology but this technology will have greater impact on clinical medicine.

Briefly stated the problem is that of adequately montirong the physiological status of an individual without interfering with tasks which will now involve free movement in a shirtsleeve environment. As will be shown, this problem has an interesting parallel in clinical medicine.

This issue of this journal is too small to explore all the arguments of what constitutes adequate monitoring. Instead it will be assumed that the EKG will be monitored. EKG monitoring will certainly illustrate some of the more general problems of continuous monitoring.

Why personal telemetry? The only reason that wires have been tolerable to date has been the physical constraints imposed by operations; the small degree of freedom afforded by the capsule or the required tether and lines for EVA. There are many other advantages of telemetry which all too often only become obvious with its use.

The following [redacted] is a list of requirements imposed by planned space laboratory operation.

Transmitter -- Accurate artefact (noise) free transmission of data

Utter reliability

Go -- no go, adjustment free operation

Small size (3-4 cubic inches maximum)

Battery life greater than duration of mission - 30 + day minimum

Resistant to shock, vibration and a wide range of pressure and temperature environments

Minimum leads including antenna (preferably no antenna)

Fail safe as regards the subject

Short range, currently on the order of 50'

Receiver -- meet above requirements plus adequate output

It is interesting to compare these requirements with those laid down at the beginning of a development program in a hospital in 1959.

FIGURE II - The block diagram of a system is shown in Figure II.

At this time it may be worth the effort to explore the various requirements in some detail. The EKG signal [redacted] may be considered to consist of three time synchronized rotating potential vectors in a volume conductor, the human body. The potential between any two points on the body will be a scalor representation of some aspect of the vector. This location or lead has been standardized in clinical practice. These clinically standardized leads or locations are not always suitable in telemetered monitoring, especially of active subjects. Several considerations are present in the choice of lead for telemetry including (1) presence of desired components of the EKG at suitable amplitude, (2) minimum interference from other active muscles, (3) minimum physical interferences and maximum comfort to the wearer. The first consideration is determined by the use for which the EKG is to be used. If it is to be useful for monitoring of arrythmias, for example, all three vector components must be visible. However, if only rate monitoring is required, then only the R.S. complex is required since this is universally used for the reference signal in cardiotachometry. Figure II illustrates this difference in waveform from two different electrode locations. Also determined at this time is the necessary frequency pass band. If the system is to be used only for rate, it is obvious just from inspection of the recorded signal that the band pass required for the R.S. segment is for less than that for all components. In practice a band from to H_Z is typical. Conversely, if all components are to be transmitted very strict limits, especially of the lower frequencies, must be observed. Probably the most frequent and serious sin committed by engineers handling of physiological signals is reduction of band pass to improve signal to noise while modifying the character of the signal itself. All too frequently the physician is unaware of what time constants are much less what the effect on the signal may be. In the case of the EKG, one of its diagnostic features is any decrease in the level of the S.T. segment below the zero line.

Frequency response: There are a number of studies which analyze normal and pathological EKG in terms of frequency. The upper frequency limit has in fact been set by previous limitations of recorders which have limited the information available for study. Since electrocardiography has been and still is an empiric rather than theoretical art, the knowledge for employment of information above say 60-70 cycles doesn't exist. There is evidence that considerable information about pathology of the heart may be present in the 50-200 CPS region. The minimum upper limit might be taken as 50 C.P.S. The lower frequency limit causes more trouble for several reasons. From the engineering view point these frequencies are at best hard to deal with and worse, many of the motion artefacts are of low frequency so in the past many have been unable to resist the opportunity to clean up the signal and thereby introduce introgenic disease. There are few really positive, unequivocal studies in medicine but one of these is S.T. segment level depression in the electrocardiogram. If this area (shown in Figure) is 100 µV below the isoelectric line, it is an indication that the heart muscle is receiving insufficient blood flow, i.e., coronary artery disease. However, too short a coupling time constant will allow introduction of an undershoot by the typically large upright pulse like R.S. complex. The fact that few researchers or physicians have read ______________________________ is evident from the large number of reports in literature of abnormal EKGs obtaine d during exercise by telemetry. If the EKG is to be used for monitoring, a system time constant of six seconds is a minimum.

If it is to be used only for heart rate determination, then there ~~are~~ -- is every advantage to pass only the information of interest, the QRS complex. There is considerable disagreement on frequency range required for this, and it varies from individual to individual and every worker seems to have different limits but ____ to ________ is reasonable.

Whether used only for rate or for monitoring, the amjor difficulty in EKG work is noise (artefact). This may be separated into three categories:

1. Extraneous electrical interference
2. Movement artefact
3. Muscle or intrimaic bioelectrical interference.

Electrical interference will of course vary greatly with the situation and could include RFI and a host of sources but to date the chief source is voltages coupled from the power mains to both equipment and patient. Since the grounding between subject and machine there exists some potential difference between the two. Conventional techniques rely on a high common mode rejection differential amplifier arrangement. One great advantage of a small telemetry system is that its capacitive coupling is to noise sources isvery small, i.e., it is so isolated that it assumes the same potential as the patient and very closely approximates a true differential device. With a single ended input system and decent electrodes, say 10,000 impeadance, it is not difficult to demonstrate equivalent CMRR of 120 db. While many of us have never used a differential amplifier input with telemetry systems, others feel that it is advantageous and with high impeadance electrodes, this may be the case.

Movement artefact may arise from many sourcesincluding electrodes, variation in R.F. field strength affecting transmitters or receivers and detuning of transmitter by relative motion. In a well designed system, the list may be reduced to electrodes (to be treated later) and variation in R.F. fix field, which invariably occurs with personal transmitters on active subjects, feeding through the receiver. This occurs when the operating poir of a device is affected by R.F. amplitude variations which are in the signal pass band going through as a signal. The obvious answer is to decouple the transmitter elements by chokes and bypasses but one is fortunate if this is required only at the input for post amplifier circuits such as a SCO frequently require decoupling as well. Just the heart produces