MEMO ROUTING SLIP	*Never Use for Approvals, Disapprovals, Concurrences, or Similar Actions*		ACTION
1 TO	~~Maj. Wittmer~~ J.W.	INITIALS	CIRCULATE
		DATE	COORDINATION
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			INFORMATION
3		X	NOTE AND RETURN
			PER CONVERSATION
4			SEE ME
			SIGNATURE

REMARKS

FROM	DATE 17 Jan 67
Ord	PHONE

DD FORM 1 OCT 60 **95** Replaces DD Form 94, 1 Feb 50, and DD Form 95, 1 Feb 50, which will be used until exhausted. c48—16—78279-2 GPO

MEMO ROUTING SLIP

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	INITIALS	ACTION
1 TO AMBB (Lt Col Ord)	INITIALS	CIRCULATE
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REMARKS

The attached work statement is aimed at achieving a highly refined personal telemetry system potentially usable in the MOL. The effort may prove quite valuable if Douglas encounters problems in this area. The equipment can be used in local MOL simulations.

FROM	DATE
SMSB (Mr. Adams)	16 Jan 67
	PHONE 4246

DD FORM 1 OCT 60 95 Replaces DD Form 94, 1 Feb 50, and DD Form 95, 1 Feb 50, which will be used until exhausted. 048—16—78279-2 GPO

EXHIBIT A

STATEMENT OF WORK

DESIGN OF A PERSONAL TELEMETRY SYSTEM FOR USE IN A MANNED ORBITING LABORATORY

1.0 INTRODUCTION:

1.1 The heart beat derived from the electrocardiogram is an easily sensed parameter that is highly useful for monitoring crew members engaged in prolonged space flight. Average heart rates, for example, indicate the relative cardiac cost of various work tasks and exercise. The beat-to-beat or "instantaneous" heart rate can be used to derive respiratory information from respiratory sinus arrhythmia and to study pacemaker response to cardiovascular stimuli. Beat-to-beat heart rates also have value in detecting rhythm disturbances.

1.2 To obtain maximum benefit from heart rate data the heart beat of each crew member should be sensed and recorded continuously. This signal can be monitored on the ground in real time whenever the vehicle is over a ground receiving station. It can also be converted into a beat-to-beat rate signal which can be stored on an on-board magnetic tape recorder. The accumulated information can then be dumped periodically to the ground, thus providing continuity of data.

1.3 Since the crew members in a manned orbiting laboratory will be mobile and highly active their heart beat must be obtained without any impairment or hinderance. It would seem possible to meet these conditions by using a small, low powered telemetry link between each crew member and the vehicle data processing equipment.

1.4 It is obvious that any personal telemetry system used in a manned orbiting laboratory will have to be highly reliable, require virtually no maintenance or attention, work regardless of the activity or location of crew members, be small in size, require little power, be immune from interference, and not interfere with vehicle telemetry or communications equipment. That portion of the system worn by each crew member will have to be small, lightweight, comfortably attached, non-encumbering and capable of being worn under a pressure suit should a sudden loss in cabin pressure occur. It is envisioned that the transmitter would fit into the pocket of a constant wear garment which contains electrode sensors.

1.5 The goal of the effort to be undertaken by the contractor is to: (a) study the numerous design approaches that could be used in a personal telemetry system for a manned orbiting laboratory; (b) experimentally evaluate the most promising designs or equipment; (c) determine the best possible design approach considering size, power consumption, performance, reliability, interaction with vehicle electronic equipment, etc.; and (d) design, develop, fabricate, test and deliver the personal telemetry system selected.

2.0 BACKGROUND:

2.1 Numerous types of personal telemetry systems have been reported in the literature. Personal telemetry instruments are also available on the commercial market. Despite their existence it is highly doubtful if any of these devices are capable of continuous, reliable, unattended operation for periods of at least 30 days in a space vehicle. Attainment of these difficult criteria will require an extensive design effort that arefully weighs the interaction between modulation technique, frequency stability, system reliability, size, system complexity, power consumption, etc.

2.2 For example, some personal telemetry units use simple frequency modulation in the 88 to 108 MHz bands. The transmitters in these systems are very simple, consume little power and can be made quite small. They are, however, susceptible to drift in carrier frequency due to temperature variation, change in supply voltage, component aging, and body movement. The drift problem might be solved by using a receiver which had an automatic signal tracking capability. Such a receiver would, however, be fairly complicated and thus more prone to failure.

2.3 An alternate approach might be to use a crystal controlled FM/FM transmitter with a crystal controlled receiver. Such a system would probably require a somewhat larger transmitter. Also, a sub-carrier discriminator would be required. Both this discriminator and the transmitter sub-carrier oscillator would have to be highly stable or, again, a signal tracking discriminator would have to be used with an attendant increase in system complexity and a probable reduction in total system reliability.

2.4 A third approach might be to use pulse modulation. Pulse modulation techniques, especially the carrier "on-off" type would reduce the duty cycle and therefore possibly cut transmitter power consumption. Pulse counting equipment can be made quite stable and small. However, transmitter size, simplicity of design, and reliability must be duly considered.

2.5 Selection of operating frequency is another problem that must be examined. Here attention has to be given to interference with other radio frequency equipment, the effects of the body on signal radiation, transmitter radiation efficiency and signal reception within the vehicle.

2.6 The USAF S hool of Aerospace Medicine has had considerable experience with personal telemetry systems. It has developed an instrument which should receive consideration for use in a manned orbiting laboratory. This system uses simple frequency modulation in the 88 to 108 MHz band. The frequency stability of the transmitter is 0.5 MHz over a temperature range of - 20 to + 100°C. Signal radiation is achieved directly from the tank coil of the oscillator. The radiated power is approximately 75 micro-volts per meter at 50 feet. The deviation-to-signal ratio of the trans-mitter is approximately 20 KHz per 100 millivolts. The transmitter requires plus 6.75 volts at 830 microamps.

2.7 The amplifier portion of the unit has a differential input. It employs Field Effect Transistors which enable an input impedance of greater than a thousand megohms to be achieved. The frequency response of the amplifier is down 3 db at 2 Hz and at 50 Hz. The gain of the amplifier is 59 db over a temperature range of 0 to 60°C. The common mode rejection of the amplifier is greater than 80 db. The amplifier requires plus 6.75 volts at 400 microamps and minus 6.75 volts at 300 microamps.

2.8 The amplifier-transmitter unit works very effectively with dry electrodes having an inter-electrode impedance in the vicinity of 200 K ohms to 1 megohm at 30 Hz. The frequency of the transmitted signal is not altered to any appreciable extent by body movement. The transmitter requires no external antenna and radiates a usable signal in all directions. The size of the amplifier-transmitter unit including batteries is approximately 85 cubic centimeters. Battery life with Mallory Type TR115R mercury batteries is 5 days if the positive and negative supply batteries are not interchanged and 8 days if they are.

2.9 An extended range automatic frequency control (AFC) device has been designed for use with the FM transmitter. This unit is added to a conventional FM receiver which has an automatic frequency control, one RF stage before the mixer and 3 IF stages before the limiter.

2.10 The extended range AFC device consists of a integrator and a sweep unit connected in the AFC line from the discriminator. The integrator tracks the discriminator output over the full range of the "S" curve. When the automatic gain control voltage drops below a certain point a sawtooth sweep generator is actuated which causes the receiver to sweep over a range of 2 MHz. As soon as the signal is recaptured the sweep device automatically turns off. With such a unit slow drift in transmitter frequency can be tracked and the receiver will automatically hunt for the signal should it be momentarily lost due to a signal dropout or change in batteries.

3.0 SCOPE OF WORK:

Contractual effort will be divided into two phases. The contractor's efforts will include but not be limited to:

3.1 Study and Evaluation (Phase I) - The contractor will:

3.1.1 Thoroughly examine all design approaches currently being used in various personal telemetry systems, giving attention not only to commercially available devices but also those reported in literature. (A personal telemetry system is defined as all those functionally integrated components and instruments existing between the ECG signal input connections and the final demodulated signal.)

3.1.2 Perform laboratory evaluations of the more promising systems.

3.1.3 Carefully compare all existing personal telemetry systems in a trade-off study that takes cognizance of the requirements set forth under Sections 4. Objectives and 5. Criteria.

3.1.4 Prepare reports of the trade-off study and the proposed design approach which represents an optimized, highly feasible design as determined by the trade-off analysis. A briefing and review meeting concerning the above will be held at the contractors facility 60 days after the contract has been negotiated. Approval by the Air Force Contract Monitor of a specific design approach will be given after this meeting and before the contractor proceeds to Phase II.

3.2 Design, construction and test (Phase II): The contractor will:

3.2.1 Design, develop, construct, assemble, test and deliver working telemetry systems, capable of transmitting and receiving the heart beat of two crew members simultaneously.

3.2.2 Provide appropriate reports, test results, wiring and schematic diagrams, illustrations and operating instructions.

3.3 The end item equipment produced under this contract will be a working prototype system which can be further evaluated as an experimental unit in Air Force laboratories. It will not be necessary for the contractor to flight qualify hardware, package it for flight qualification, or to use components or construction techniques that conform to Military Specifications. The design approach selected should, however, permit flight hardware to be developed at a later date without the need of a major redesign. The equipment delivered is to be functional, durable and capable of being used in space cabin simulators.

3.4 Extreme miniaturization is not the primary goal of this contractual effort. It is felt that size specifications should be attainable without the need for special construction techniques or the use of costly microcircuit components. The Air Force will consider modifying volume specifications should the contractor feel that these will be needlessly difficult or costly to achieve.

3.5 The contractor shall deliver all contract end items within 270 days of receipt of a negotiated contract.

4.0 OBJECTIVES:

4.1 The purpose of the proposed effort is to arrive at a system which will successfully telemeter the heart beat of active, mobile crew members during prolonged space flight. The system used for this purpose will consist of those amplifiers, transmitters, receivers, discriminators, demodulators or other components or instruments needed to amplify the electrical potentials of the heart and relay them to fixed data processing equipment in such a form that they can be converted into heart rate information.

4.2 The equipment assembly required to sense, transmit, receive and demodulate the heart beat, a so-called "personal" telemetry system, must be capable of continuous, reliable, unattended operation in a space environment for periods of at least 30 days. Transmitter batteries can be replaced at intervals but it should not be necessary for the crew members to spend any other time in adjusting or calibrating the equipment.

4.3 The personal telemetry system is to be capable of operating from balsa wood lithium chloride "dry" electrodes. (Fischmann, E. J., Seelye, R. N., and Crutcher, L. R.; Clinical Trial of a Balsa-Lithium Electrode for Conventional Electrocardiography; American Journal of Cardiology; 10: 846-851, Dec 1962). These electrodes will be held against the skin by a strap thus avoiding the need for adhesives. No skin preparation or electrode paste will be utilized. Such electrodes have a source impedance ranging from 200 K ohms to 1 megohm at 30 Hz when applied as stated.

4.4 The personal telemetry system designed by the contractor does not have to transmit an electrocardiogram of clinical quality. It need only transmit the QRS complex. The R-Wave of this complex should not be distorted since it will be used to trigger other equipment.

4.5 The personal telemetry system designed by the contractor is to be capable of transmitting a usable signal from any location within an empty metallic cylinder, 10 feet in diameter by 20 feet in length without the use of any external signal radiator on a crewman's body other than the electrode leads. (It is assumed that the receiving antenna(s) are located within the cylinder.)

.6 That portion of the equipment worn by a crew member shall be small, lightweight and designed to be located near or next to the body. Operation shall not be adversely affected by body moisture or the position of the transmitter relative to the skin.

4.7 For the purpose of this contract it will be assumed that the personal telemetry system will be used in a space craft which employs the same type of radio frequency devices as those used in the Mercury and Gemini programs. It will not be necessary for the contractor to obtain exact frequencies of this equipment or to select a specific channel for operation of the personal telemetry system. He should, however, select a band taking into consideration interference, signal propagation, absorption or re-radiation of energy by the body, availability of equipment, and the reliability of such equipment.

4.8 It will not be necessary for the contractor to design the sensing electrodes, determine the best placement of such electrodes, or design the equipment used to convert the R-Wave into heart rate information. Information in these areas will be made available by the USAF School of Aerospace Medicine. The School will also supply data on the personal telemetry equipment that it has developed.

4.9 It will not be necessary for the contractor to supply flight qualified or "flight qualifiable" hardware as a final contract end item nor will it be necessary for him to perform flight qualification tests or to use parts or construction techniques that conform with existing Military Specifications. The design approach and components selected by the contractor should, however, be compatible with the ultimate development of flight qualified hardware.

4.10 The contractor is to identify all significant signal radiations from the personal telemetry system including harmonic radiations from the transmitter and all radiations from the receiving equipment.

4.11 It is not necessary for the personal telemetry system to be supplied with a QRS signal amplitude calibration device. Although the amplitude of the QRS signal may vary with temperature or battery aging such alterations will be acceptable so long as a sharply defined QRS component appears in the output of the receiving equipment. Such a signal shall at all times be at least 3 times the amplitude of any system noise, assuming a constant amplitude ECG.

4.12 The personal telemetry system shall contain an externally accessible single-ended connection which can be used to obtain the heart beat signal at those times (launch and re-entry) when it will be desirable to carry the heart beat signal from the crew member by hard-wire to vehicle data processing equipment. Signals obtained from such a tap must provide a QRS component which is at least 3 times the amplitude of any system noise or any electrical artifact that might be received from the electrodes (exclusive of motion produced artifacts.)

5.0 CRITERIA:

The personal telemetry system developed under this contract shall have the following characteristics:

5.1 Transmitter:

5.1.1 The transmitter shall be no larger than 100 cubic centimeters including batteries. The longest dimension of the unit shall be less than 10 centimeters and its thickness shall be less than 3 centimeters.

5.1.2 The weight of the transmitter including batteries shall be less than 150 grams.

5.1.3 The life of the batteries used in the transmitter shall be such that 6 days (144 hours) of continuous operation can be achieved before battery replacement is required.

5.1.4 The transmitter shall use no external signal radiator other than possibly the electrode lead wires. These wires will be no longer than 45 centimeters and shall be capable of being placed in any configuration against the skin.

5.1.5 The transmitter shall be capable of operating from dry balsa wood lithium chloride impregnated electrodes. These electrodes when pressed against the unprepared skin generally have a source impedance of 200 K ohms to 1 megohm measured at a frequency of 30 Hz. To avoid signal distortion it is suggested that the input impedance of the ECG amplifier be greater than 20 megohms.

5.1.6 The transmitter shall be capable of continuous, satisfactory operation for periods of at least 30 days without adjustment or attention other than change of batteries.

5.1.7 The transmitter shall be immune from the effects of body moisture and movement relative to the body.

5.1.8 The transmitter shall generate a usable radio frequency signal regardless of the location of a crew member within an empty metal cylinder 10 feet in diameter and 20 feet in length. (It is assumed that the receiving antenna(s) can be located at any position within the cylinder.)

5.1.9 The transmitting unit shall be designed and packaged in such a way that it has no sharp edges or rough surfaces.

5.1.10 The transmitter shall be capable of operating over the range of 0 to 50°C without deleterious effect on the signal appearing at the output of the receiving system.

5.1.11 The transmitter unit is to be supplied with a single-ended tap for hard-wire connection. The signal level at this tap shall be at least 1.0 volt peak-to-peak across a 500 K ohm load when a 1 millivolt peak-to-peak signal is applied to the input of the amplifier portion of the transmitter. The input of the amplifier should be differential and the amplifier stages preceding the tap should have a common mode rejection ratio of at least 80 db.

5.2 <u>Receiver</u>:

5.2.1 The receiver portion of the personal telemetry system shall be designed in a manner that each receiver has a volume less than 3000 cubic centimeters.

5.2.2 The receiver shall be designed so that it consumes less than 7.5 watts of power at 28 ($\pm$ 4) volts dc.

5.2.3 The final demodulated output signal of the receiving device shall be 3 volts peak-to-peak across 1 K ohms when a 1 millivolt peak-to-peak signal is applied to the input of the transmitting unit.

5.2.4 The receiver shall be capable of operating reliably at temperatures between 0 and 50 degrees centigrade. It shall be capable of withstanding temperatures from - 30 to + 60 degrees centigrade.

5.3 Total System:

5.3.1 The total personal telemetry system shall be capable of "hands-off", reliable, continuous operation for periods of 30 days excluding changes of transmitter batteries. The total system shall have a meantime-between-failures of at least 7,000 hours.

5.3.2 The overall frequency response of the system (data signal) should be flat between 2 Hz and 50 Hz (3 db points).

5.3.3 The total system signal-to-noise ratio under the worst operating conditions should be at least 3 to 1 at 30 Hz.

5.3.4 All radiations from the transmitter and the receiving equipment shall be clearly identified as to frequency and relative level including any harmonic or other spurious radiations.

5.3.5 The personal telemetry system shall be capable of operating at an altitude of 100,000 feet or in the presence of 100% oxygen at a pressure of 5 psia and a relative humidity of 85% in the stated temperature range.

6.0 TASKS:

6.1 The contractor is to perform the following tasks:

6.1.1 A search and study of the literature to evaluate the types of personal telemetry systems that have been developed.

6.1.2 A survey of commercially manufactured personal telemetry equipment to determine its potential suitability for the end application.

6.1.3 Laboratory test evaluations of the most promising design approaches and/or equipment.

6.1.4 A multi-parameter trade-off analysis that weighs such factors as size, weight, power consumption, reliability, modulation technique, operating frequency, system complexity, operating characteristics, etc.

6.1.5 Selection of the most promising design approach based on the trade-off study.

6.1.6 Fabrication and construction of a system capable of simultaneously monitoring two crew members.

6.1.7 Test of the personal telemetry system. Tests will be performed to insure that electrical and environmental specifications are met, as well as operational tests. Operational tests of the system will be made using electrodes of the balsa-lithium chloride type. The Air Force will supply the electrodes for the operational tests.

6.1.8 Preparation of reports, test data, diagrams and drawings.

7.0 PERIOD OF PERFORMANCE:

7.1 The contractor shall deliver all equipment and reports 270 days after issuance of the contract.

8.0 DATA AND REPORTS:

8.1 The contractor shall provide an oral briefing for the contract monitor concerning the literature search, trade-off analyses, preliminary test evaluations, and tentative design approach on or before the 60th day after issuance of the contract and prior to the fabrication of end item hardware. The contractor shall also provide informal monthly progress reports. At the conclusion of the contract period the contractor shall provide the reports listed in the attached DD Form 1423.