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Bid No. 76 - 1

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May 4, 1953

ENGINEERING PROPOSAL

PORTABLE INFRARED COMMUNICATOR

Research and Development Objective

The objective of the research and development which is outlined in the following is to create a portable two-way infrared voice communication system of small weight and size with a maximum range of 20 to 25 miles and a minimum range of 3 to 5 miles. The system shall be capable of operation with a very high degree of visual security. Daylight operation shall be possible with a minimum decrease of range. The system shall be capable of being set up, adjusted for operation and operated with relative ease and no especial knowledge of electronics by the operating personnel. The equipment shall be capable of being stored for long periods of time and under adverse conditions without appreciable loss of operating effectiveness.

Phase I - Proposal for Research and Development Program

In the research and development phase of the above program, it is proposed that a study be made of transmitter and receiver components and their combinations to achieve

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maximum performance with minimum size and weight. Thus the comparative sensitivity in the useful IR regions of photoconductive vs. photomultiplier cells will be studied, in view of their ultimate contribution to range, as against size and complication of amplifiers and power supplies required by the two devices. The use of transistor amplifiers will be considered in view of low noise requirements and the need for various filter arrangements for band pass operation. It is proposed to evaluate relaxation transistor oscillator high voltage power supplies against miniature voltaic piles or more conventional means for powering a multiplier phototube. Methods for wide angle "FIND" arrangements, with single tones and sharply peaked filters, in the receiver amplifier for easy "ADJUST", leading to very narrow angle, wide frequency band OPERATE conditions will be evaluated. Similarly in considering the transmitter, it is proposed to evaluate extremely light weight sources of power, various methods for achieving modulation without excessive use of power or large complicated mechanisms, and methods for achieving maximum reflector area in a minimum overall package by using the same reflector for both transmit and receive. Latest technics in coated reflecting surfaces and coated filters will be studied to achieve highest security. Multiple sources will be considered for the "FIND" and "ADJUST" functions. Overall miniaturization design will be considered in this phase also. Mechanical designs suitable for portable use and yet adequate for field service will be studied.

At the completion of the study phase outlined above, it is proposed that the Contractor call a design conference at such time as may be convenient to the Agency engineering personnel. Further progress on the task will be as outlined in agreement reached in this conference as to the directions considered most promising of those revealed in the above studies.

<u>Phase II</u> - <u>Proposal for Engineering Development Program</u>

The above studies will have indicated the types of transmitter receiver system best suited for development, based on theoretical evaluation. In this second phase it is proposed to investigate practical means for turret mounting the receiver and transmitter elements to achieve the unified mirror arrangement indicated above, as well as suitable means for combining wide angle "finding" and "adjusting" with very narrow angle voice operation.

It is proposed to investigate a source of power to give maximum output with minimum size and weight. At this time it appears that well known technics might be combined to give the desired result with the added advantage of long storability and ease of supply almost anywhere in the world. Another type of source will be studied which gives maximum battery power with minimum weight, along with good storability; and it will be considered if transmitting power can be reduced sufficiently by the proposed wide beam high power "find", narrow beam low power "operate" system. Push-to-talk operation would give not only the advantage of being able to use one large mirror in place of two small ones but would also conserve source energy. So also would speech operated beam relays, for while a tungsten source is too slow to modulate directly, its speed is probably sufficient to allow such use with negligible clipping. This investigation would be combined with practical approaches to the modulation problem with the German Lichtsprecher arrangement of a vibrating prism as one approach, vibrating mirrors another and direct defocussing either axial or lateral, as a third possibility.

The requirements of low operating power and maximum range both predicate the use of narrowest possible speech band pass with emphasis on transmitting the most power in the frequency regions of maximum intelligibility. There is evidence which should be investigated that the nature of the pass band to achieve the above is composed of a continually rising response curve from a lower cutoff in the 500 to 700 cps region to a sudden cutoff at approximately 3000 cycles per second. Such a pass band may conceivably have no greater noise contribution than one peaked at 1500 cycles, while the intelligibility should be considerably better.

It is proposed that in the "Find" alignment the possible use of the same circuitry for the modulating oscillators and the narrow pass band filters on receive be investigated. To facilitate the alighment, mechanical means for micrometer adjustment of perhaps $\pm 5^{\circ}$ in azimuth and elevation on a very light weight tripod mount are proposed. Note that hand held devices are definitely not to be considered for long-range operation, however, the handset might be hand-held, or perhaps preferably, the microphone might be part of the main tripod-mounted unit while a separate headset allowed the operator to move freely with respect to this unit. Even the headset might advantageously be tuned to the same pass band as the rest of the system.

It is proposed that as the result of the above investigations, <u>at least two sets of equipment be designed and built up as Design Approval Models</u>, using the best types of the above alternative methods. These systems would be evaluated by Agency personnel for performance against the criteria considered most desirable by the Agency. The result of this preliminary evaluation would be the determination of the system to be incorporated in Development Models which will be finished for Agency field evaluation tests. These Development Models of which it is proposed that 10 sets (20 units) be fabricated, would incorporate all modifications agreed upon between the agency and the contractor as being desirable and practicable.

Phase III - Proposal for Preproduction Program

Phase III is understood by the contractor to cover the production of additional equipments which will be called Pre-production models. This phase would finalize the design of tools, jigs, fixtures and test equipment along with design revisions necessary for mass production of the device as developed in the above program. This phase would also include preparation of time study data and proposed factory layouts to cover the production of the units at any rate proposed by the Agency.

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Phase IV - Proposal for Pilot Run Production Program

This Phase IV covers the production of a pilot run quantity to prove the tooling, jigs, fixtures, time studies, plant layouts etc.; after which pilot run, such equipment would be stored by the contractor at such cost as may be mutually agreed upon in order to be prepared for any eventuality which may direct the production of larger quantities of the equipment on short notice.

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PORTABLE INFRARED COMMUNICATOR

Task I Phase I

In compliance with a request from the contracting agency, the following detailed engineering proposal covering Phase I of Task I is submitted for your consideration.

A. Material. A list of estimated experimental material follows. It is to be noted, first, that it must be assumed all important components of the optical systems, power sources, and mechanical adjustment systems etc. will be purchased especially built to Raytheon specifications and for this reason as well as because very small quantities will be involved, unit costs will be relatively high; and second, that these estimates cover several types of each description for comparative study.

Phase I of Task I, Materials

Item	Quantity	Description	Unit Cost	Total Cost
1	6	Mirrors	$ 120.00	$ 720.00
2	6	Photomultipliers	2,000.00	12,000.00
3	10	PbS cells etc.	50.00	500.00
4	30	Special lamps	150.00	4,500.00
5	3	Special Gasoline Engines	1,500.00	4,500.00
6	3	Special Generators	500.00	1,500.00
7	5	Silver Cell Batteries	150.00	750.00

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Engineering Proposal
Task I, Phase I

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Item	Quantity	Description	Unit Cost	Total Cost
8	3	Mirror Modulators	$500.00	$1,500.00
9	3	Special Phones	80.00	240.00
10	3	Tripods & Heads	120.00	360.00
11	3	Trim Mechanisms	250.00	750.00
12	lot	Mallory Cells	-------	150.00
13	lot	Other Electronic Parts-------		4,000.00
14	lot	Other Mechanical Parts-------		8,000.00
		Material Total, Phase I of Task I		$39,470.00
15		Test Equipment for Sensitivity tests, etc.		1,000.00
		Material and Test Equipment Total, Phase I of Task I		$40,470.00

B. Manpower. It is estimated that a total of 6,453 engineering labor hours will be expended in Phase I of Task I as follows:

Division Chief and Project Engineers	1051 hours	
Other Electronic Engineers	1313 hours	
Technicians	788 hours	
Mechanical Engineers	1576 hours	
Total Infrared Lab. Engineering		4728 hours
Draftsmen	675 hours	
Model Shop	1050 hours	
Total Service Engineering		1725 hours
Total Engineering Labor, Phase I of Task I		6453 hours

C. Procedure. In Phase I of Task I, a large number of studies will be undertaken, both theoretical and experimental, in an effort to arrive at parameters and devices which can be used to design the longest range and smallest size and weight into a high quality infrared communicator. Descriptions of a number of these studies follow.

1. The infrared detector element. Studies will be made comparing the sensitivities of photo-conductive cells such as lead sulfide, thalofide, and lead selenide cells, against the sensitivity of multiplier photo-cells designed especially for the infrared region, for use with an incandescent tungsten source over the speech frequencies. Thus the extreme sensitivity of the photomultiplier must be weighed against its relatively high noise level when designed for the infrared, its fairly large target area, and its narrow spectral response. On the other hand, the excellent noise level, the extremely small size, and the wide spectral response of cells of the lead sulfide type must be weighed against their relatively long time constant and somewhat lower basic sensitivity.

2. The beam width. Since long range communication with small power can only be achieved with a very narrow beam, and since it is difficult for each station to find the other and establish communication unless the beam is quite wide, we will study the feasibility of designing a source whose beam width can be made wide for establishing communication, and narrowed down while maintaining communication at greatly reduced input power. Special incandescent lamps with multiple filaments will be considered such that the central, communicating filament is surrounded by one or a number of extra filaments which are energized only during

the time necessary to find the other station and adjust to maximum response. Various coding means for adjusting quickly and accurately to the center of the other stations beam will be studied. A study will also be made of means for supplying the additional power for these filaments for the short period they are in operation without reducing materially the overall operating time of the equipment.

3. The reflector area. Since the transmitted energy and the received energy are each directly proportional to the area of the respective reflector, it is clear that the larger these can be made the greater the range of the system will be. It is therefore the subject of one major proposed study to consider the feasibility of using one large reflector for both receive and transmit rather than two small separate ones occupying about the same size case. Thus one 7" diameter mirror would equal the combined areas of two 5" mirrors: one 10" diameter would equal the combined area of two 7" mirrors, etc. The mechanism required for switching from receive to transmit might become involved, but if it could be simplified, such a device would be very worth while developing.

4. The modulation means. Cesium lamp sources, which can be readily modulated directly, are not adaptable to low power operation or to narrow beam widths. Moreover they cannot be used in the intermediate infrared. On the other hand, the tungsten filament which

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is usable in both near and intermediate infrared at both low and high powers, and narrow or wide beams, is not suitable for direct electrical modulation due to the thermal lag of the filament. We will study other means for modulating the output of the tungsten filament. Vibrating mirrors, grids, defocussing devices and total internal reflection schemes will be compared, with the aim of arriving at a method giving the highest efficiency and the best intelligibility in the most compact arrangement.

5. The source of power. It is proposed to study the applicability of a very small high frequency generator to the output of a very small high speed gasoline engine arranged for quiet operation. Such a combination should provide the most compact, long running power source at present achievable, and have the further advantage that gasoline for its operation should be readily available anywhere on earth. To compare with such a source, a study will be made of light weight, high ampere hour capacity batteries such as the Silver Cells, for use should only very low power be required to achieve satisfactory ranges.

6. Other studies. Other studies will be made on the relative merit of various types of high voltage power supplies for the photomultiplier tubes and the amplifiers; band pass filter arrangements; the applicability of transistors to the amplifiers; devices for achieving maximum visual security, and the general

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shape factor and mechanical packaging of the equipment. It is to be noted in the above that no finished model will be the outcome of the above phase but rather that data and components will result which can be chosen for incorporation into design approval models in the first stage of Phase II.

7. The above program is not intended to be all inclusive nor exclusive but portrays the initial origins of the Study Phase.

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4. BACKGROUND INFORMATION:-

a.- Related MOCs and allied information in attached list.

b.- Workable models should be available for service- testing within one year from initiation of project.

II OPERATIONAL CHARACTERISTICS

1. Frequency coverage limited to a single voice channel; probably located within "near" infra- red spectrum, from 0.8 to 1.2 microns, as used in comparable Military equipments, but both reliability of propagation and minimization of weight, bulk, and power requirements should be considered in selecting most suitable operating range within the IR spectrum, regardless of compatibility with other systems.

2. Emission Designation; Normal voice modulation, with fair degree of voice recognizability is the primary requirement. If a secondary capability for Morse operation, possibly using special goggles for code reading, in lieu of the more noticeable earpiece necessary for voice, is easily includable, it would increase the utility of the equipment. Pocket operation of a handkey, under possible observation, would also be occasionally desirable as being less obvious than use of a microphone.

b.- TRANSMISSIONS will be intermittent; generally two- way alternately, but occasional requirement for one- way only operation, where possible with previous determination of beaming angle or spread etc will develop. If simply feasible, means for focusing or beaming on a distant target, with little or no return information from the distant target, would be helpful.

c, d.- Supplementary characteristics, bandwidth; in addition to physical concealment, probability of detection or interception of the communications, or even knowledge that signalling is occurring, should be minimized.

3. RANGE OF TRANSMISSION/RECEPTION: Effort should be made to provide minimum range of one and one half statute miles, under worst expectable weather conditions; any possibility of penetrating light screening, such as shrubbery, or exploiting reflective properties of commonly encountered structures or natural formations, should be explored.

3. (Cont.) If physically supportable, alternate use of master- and- slave operation, with passive reflector at one station, and transmitting equipment and power requirement concentrated at the other station could be useful where one station had relative freedom of movement and operation, and extreme caution was required at the other station.

4. SPATIAL COVERAGE; since communication between two fixed, or slowly moving points, is necessary, a narrow beamwidth id desirable, both to minimize detectability and to maximize signal power during communication. However, for preliminary orientation, communication in motion, and possible beacon use, availability of a broader beamwidth would be desirable, if simply feasible.

Orientation of beam should preferably be feasible by movement of the operator's body, with minimum of equipment adjustments necessary, beyond possible adjustment of beamwidth, if feasible, after initial contact. Final beamwidth should be sufficiently broad that minor body movements will not disrupt contact.

5. Interference elimination is anticipated as a minor problem.

6. Identification; Voice recognition will probably provide best identification means; however, any inherent features of the medium which can simply be used recognizability should be exploited.

7. STABILITY; should be the maximum attainable with considerations of physical simplicity and security held as the prime governing factors.

8. RESOLUTION AND DISCRIMINATION; Sufficient to provide recognizable voice communications.

9. ACCURACY & FIDELITY: as above.

10. Operation for over 30 minutes per contact should not be necessary, with opportunity to replace or recharge batteries between contacts if required. Normal operation of 15 minutes per contact, including line- up time, should be feasible.

III PHYSICAL CHARACTERISTICS:

1. Weight and volume must not exceed what could be worn or carried by one operator, without attracting attention or causing undue fatigue over several miles afoot, over moderately rough terraine. Form factors should tend toward maximum concealment, in pockets where possible, or unobtrusive harness mainly beneath clothing may be used, if desirable, for support or orientation of radiating elements.

3. Normal operation will require no operation in conjunction with other electronic equipment. If found feasible, an auxiliary application to triggering a remote concealed beacon, or to transmitting brief telegraphic messages through an unattended concealed radio station might be found useful.

4. POWER SUPPLY from nearby automobile battery may occasionally be possible, but nearly all operation from self- contained batteries or other concealable power suurce must be anticipated. Provision for recharging or replacing batteries between 30 minute contacts is permissible, but undesirable if the period can be enlarged without undue weight addition.

5. ALTERATION or interchangeability considerations should not be allowed to complicate the design; replacement or servicing of batteries and tubes used should be simply possible, without requiring important readjustments to equipment. If this is impracticable, replacement of the entire unit rather than field readjustment should be made.

6. CONSTRUCTION should be sufficiently rugged to withstand hazards of occasional careless handling, but must not penalize the primary goals of concealment and transportability.

7. EQUIPMENT AND CONTROLS shall be located to permit operation with greatest possible simplicity and unobtrusiveness, preferably operable while standing, sitting, or walking slowly.

8. METERS and test equipment must be kept to an absolute minimum consistent with simple, rapid alignment and operation.

IV EQUIPMENT OPERATION AND MAINTENANCE CHARACTERISTICS:

1. Operating time; probable maximum, two one- half hour periods per day.

2. Maintenance scope; practically none, beyond battery or tube replacements. defective equipments should be replaced, rather than maintained in field.

3. CONTROL features; simplified, as above.

4. DATA Transmission N/A.

5. Special safety features; none.

6. PREPARATION PERIOD, from power- off condition; maximum of 5 minutes' warmup time is permissible, if necessary, but shorter warm- up is preferable if attainable without penalizing other features.

7. PERSONNEL CONSIDERATIONS: should be operable, after brief instruction, by unskilled, non technical personnel; battery checking and replacement shoul be very simple processes.

8. FIELD MAINTENANCE provisions should be minimized, due to nature of equipm and its employment.

9. SPECIAL CONSIDERATIONS: in addition to normally packaged and on- the- bod transportation, equipment may also be delivered by parachute drop. Due to d bulk, special shock- absorbent and waterproof packaging may be developed to minimize shock damage, and also to permit packaged concealment or burial for l recovery.

Effort should also be directed toward permitting transportation and del in as nearly operably assembled form as reasonably feasible without increa bulk or liability to damage or deterioration in transit. Any tubes, batte or other items found to require removal or disconnection during shipment o storage must be provided with error- proof cables, plugs, and markings to rapid reassembly; the number of such cables should be minimized.