necessary geodetic reference frame (this is one of the highest priority strategic reconnaissance missions).

d. To obtain technical intelligence information.

Vehicle systems will be able to contribute to the accomplishment of these missions by providing the most effective environment for the operation of the sensors and data collection systems. The most fruitful methods of collecting reconnaissance data at present are photographic, infrared, electromagnetic techniques, or combinations of these. Sonic energy sensors could also be considered for technical intelligence information. Vehicle systems are used to place these sensors in such a position that the best available data can be collected. In strategic reconnaissance uses, this placing will involve overflights of potentially hostile territory or perimeter surveys. Overflights require that the vehicles used have a low probability of being intercepted and that the vehicles themselves do not provoke aggression by being mistaken for a bombing system.

Essentially two vehicle systems are available at the present time; the 461L high altitude balloon photographic system and the U-2 high altitude subsonic aircraft system for vertical or oblique photography and ferret perimeter missions. Altitudes of both are comparable for the photographic systems. Both systems have restrictive characteristics which permit them to accomplish only limited reconnaissance missions.

Future improvements over the U-2 can be significant and will fulfill a useful purpose whether or not they are available before the WS 117L system. Since no other reconnaissance system could probably be developed between the U-2-461L programs and the satellite systems, any new or improved high-altitude aircraft system should be capable of usefully augmenting the satellite surveillance system. In order to minimize interception probabilites, it should be capable of flight above 100,000 feet. High Mach numbers are necessary to sustain flight and a range of approximately 4,000 miles is needed for many useful missions.

WS 117L is the satellite reconnaissance system being developed by the Air Force for visual, electro-magnetic and infrared surveillance of the Earth. The 117L vehicle is, essentially, the final stage of a multiple staged rocket, which, after being fired into orbit, functions as a space platform equipped with a reconnaissance system.

As pointed out previously, accurate global mapping has a very high priority on the basis of strategic necessity. It is evident that effective countermeasures against satellite reconnaissance systems can be developed, and it is almost certain that the USSR will use any countermeasures that are available. The basic question of countermeasures is one of time. The Soviets will be unlikely to affect the first satellites used, but as their capability to interfere with reconnaissance satellites develops, so will the probability of their doing so. Thus, it appears vital that good mapping satellites be developed and used as early as possible with the WS 117L satellite surveillance system.

System investigations of the NAS-ARDC Committee on Reconnaissance and Intelligence have indicated, however, that the photographic system chosen for the pioneer photographic system of the WS 117L is not satisfactory for mapping work. The panoramic strip camera and the attitude stabilization system are not adequate. Accurate photographs for mapping should be recovered physically. Attitude stabilization in orbit should include stellar observations to reduce the possibility of cumulative position errors.

In addition to man-made countermeasures, satellites are vulnerable to natural phenomona. The electronic equipment in satellites depends heavily upon transistors and transistors are very vulnerable to knock-off of atoms from their crystal lattice structure when subjected to particle bombardment. If the radiation could be changed to γ or X-rays, then long time damage effects to transistors would be greatly attenuated. Thus, it is important in high altitude orbits to know whether particle radiation exists so that shielding must be considered. The whole question of radiation intensity and distribution is so vital to the 117L program, and its follow-ons, that serious consideration should be given to early instrumented flights of 117L vehicles for this exploratory use.

As far as initial requirements for men in reconnaissance satellites are concerned, they will be primarily used on an intermittent basis. Logistic support and repair of orbiting vehicles would simplify many of the operational problems of video data link surveillance systems. If high altitude satellites require physical return of photographic data, a manned support vehicle could replenish the film and insure the safe return of exposed negatives.

In summary, the following conclusions

and recommendations can be subm ed regarding reconnaissance vehicles:

a. High altitude manned reconnaissance vehicles would be useful as complements to the 117L system if they are capable of avoiding detection or, at least, interception.

b. As soon as practical, a major emphasis of the 117L program should be placed on mapping.

c. A suitable mapping camera, vehicle stabilization system, and physical recovery data transmission system for the 117L system should be developed as quickly as possible.

d. Upper altitude radiation and physics problems should be resolved at the earliest date. The use of an adequate number of 117L vehicles for this purpose is recommended.

e. Advanced reconnaissance satellites for global surveillance, mapping, warning, weather forecasting, etc. should be developed.

f. Manned vehicles for logistic support and maintenance of satellite and space reconnaissance systems should be seriously studied in anticipation of their use.

g. Critical components of future systems should have more support than appears to be possible under the weapon systems concept.

The extent of our knowledge about the exosphere must be made comparable to that now available about the atmosphere. The number of unknowns is large, and the environment is imperfectly understood, even to a first approximation. The possibility of modifying this environment seems very real, and presents an exciting and challenging prospect: control of solar radiation at ionospheric heights, for example, could conceivably affect the energy balance in our atmosphere and thus exert an influence on the high-altitude winds which influence weather flow. But, even without looking so far, radiation may severely limit the working life of electronic components of other equipment and of human beings exposed to the space environment. Data on this problem will greatly influence design studies, especially for such applications as communication relay satellites, which well may constitute one of the first practical uses of space.

Extensive experimentation will be necessary before components can be soundly designed for long exposure beyond the atmosphere. It should be recalled that many decades of study of cosmic rays elapsed before the cosmic ray showers produced by high-energy particles were discovered. It is possible that there may be surprises of a like nature in regard to the effect of radiation upon equipment in satellites. A major problem which must be solved before a sound design for satellite equipment can be worked out is a thorough characterization of the nature of the radiation produced in a satellite. It will not suffice simply to express this in roentgens, as measured by an ionization chamber of a Geiger counter. It will be necessary to know what fraction displaces atoms from their chemically bonded positions, and what fraction produces electronic ionization without atomic displacement.

It is evident that satellite-probes, carrying equipment for the measurement of radiaton and the transmission of the information to Earth, will continue to play an important role in this field. How the emphasis should be divided between such experiments and the projection of recoverable equipment into the ionosphere is a problem requiring sound research planning which should be dealt with by a competent team of scientific experts.

Similar problems of radiation effects upon equipment occur in the case of the reconnaissance satellite. Since this subject constitutes a separate joint commitee report, it will not be dealt with further here.*

An ICBM in its trajectory in space represents a major discontinuity in its neighborhood. With our very limited present knowledge it cannot be predicted how, if at all, this disturbance may be used for detection in an AICBM system. When the scientific aspects of possible phenomena are more fully understood, system design can be undertaken on a much sounder basis.

The new altitudes reached by satellites are regions that can be substantially affected by man-made disturbances.

From the briefest consideration of these problems, it is clear that very extensive and well planned scientific experiments must be conducted before space electronics can be built on a firm foundation. This work will be expensive. In effect, the environmental and propagation information obtained in the troposphere over a period of decades must now be extended to the ionosphere, or beyond, in a period of just a few years if electronics is to meet the requirements of the Air Force.

In order that the necessary scientific information about the nature of phenomena in space be obtained with maximum speed and efficiency, new facilities and probably a new organization of scientists will be required. In brief, it is strongly recommended that ARDC establish or cooperate in establishing a space research facility planned to obtain scientific information relevant to radar, AICBM, and satellites in the ionosphere and beyond. The electronics committee strongly recommends that this program be carried out with high level priority even if this must be done at the expense of the total weight of satellites put into orbit, or other more immediately tangible evidences of "space conquest." It will be, in the final analysis, sound scientific design which will give leadership in the field.

APPLIED RESEARCH AND SOUND TECHNICAL MANAGEMENT

On the basis of discussions with ARDC personnel and on its own experience, the electronics committee concludes that an unsatisfactory program exists in the balance between applied research intended to develop the state of the art and produce development along technical lines on the one hand, and, on the other, the development and procurement of end items, particularly large systems or prototypes of large systems.

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* See "Report of the Committee on Reconnaissance and Intelligence," NAS-ARDC Study, 1958.

likely to be an immediate requirement.

The progress in the development of chaff jamming techniques has generated substantial improvement in radar techniques so that ground-based radars have much more chance of success against conventional aircraft than would have been expected years ago. On the other hand, presently planned AICBM weapon systems are completely inadequate to cope with a simple decoy and jamming effort. Means must be found to meet this threat and at the same time equip our own second generation missiles with decoys and jamming sets.

The extension of electronic warfare to missiles and satellites is an unavoidable consequence of technological progress. Satellites will soon be found to be adaptable to a number of missions well beyond reconnaissance. They are ideally suited for jamming and deceiving AICBM devices; they can be used to release chaff type devices in orbit; and they can be effective against a number of long range enemy warning and guidance weapons.

It is clear, however, that jamming and the release of chaff from satellites will necessarily have to be tightly restricted because it is in the national interest to limit "spent" satellites in orbit to an absolute minimum. It may also be found that satellite jamming will be held to be a war-like act.

SPECIAL SYSTEMS

Two special systems were considered in some detail by the electronics committee: one on satellites for communications relay purposes, and one on the AICBM problem.

Satellite relays are judged to be feasible and useful. The committee has discussed various types and has outlined possible development programs.

The AICBM problem was also examined and past studies of it were surveyed. The extreme technical difficulties appear to be nearly as formidable today as they were several years ago, and the need for research on relevant scientific problems of re-entry, decoy discrimination, and high altitude destruction is as necessary now as it was then. Recommendations for such studies have been reviewed and are re-emphasized.

Chapter 9

MILITARY USES OF SPACE FLIGHT

The purpose of this study was to assess the military uses of space flight.

In the conduct of the study it was recognized that specific military space missions must not only be feasible, but also preferable to alternate methods of achieving the same results through more conventional weapon systems. Unless a military advantage accrues from space flight, the capability of our armed forces is diluted rather than increased.

In the course of the committee's deliberations, the capabilities, missions, and developmental requirements of space flight were examined for military application. It was observed that a capability exists to inject important payloads into space and that this capability can grow rapidly in the future. A wide spectrum of potential military space applications is suggested, ranging from early limited applications to long-range, large-scale systems. Comments and conclusions are divided according to time periods.

NEXT GENERATION SYSTEMS

Next generation systems will be those which augment current weapon systems. Within this framework, the following systems deserve attention.

Long-range ballistic missile programs will become a reality. The use of such systems for increased operational flexibility is noted in terms of vehicle potential for spoofing, ranging, and limited personnel and material transport.

Orbital systems devoted to reconnaissance have a high immediate military worth. Recommendation is made to supplement the WS-117 L program with a program for physical recovery of geodetic photographic data from short-life satellites. A further need is foreseen for programs to counter Soviet reconnaissance satellites. Limited initial development and exploratory operation of communication and investigation satellites is recommended together with the creation of a decoy satellite capability.

A strong effort in the field of an unmanned work-horse satellite is urged to obtain necessary geophysical, life-science, and component design environmental information.

INTERMEDIATE PERIOD SYSTEMS

Within the next decade, orbital systems can assume prime weapon system status. Combat potential is feasible in global reconnaissance, bombardment, air defense (AICBM), and logistic support by manned vehicles and orbital platforms. The Dyna-Soar program is seen as contributing significantly to military capability in this time period. It is further noted that during this time period countries other than the United States and U.S.S.R. will achieve space capability. The impact of such an event upon our military posture deserves study. Recommendation is made for action in satellite tracking and sorting systems and in anti-satellite systems. A requirement may develop for manned orbital vehicles for logistic support, decoy and debris sweeping, orbital platform erection and anti-satellite discrimination and/or destruction.

INTERIM AND OPEN-ENDED FUTURE SYSTEMS

In the time period following the next decade, manned lunar flight and exploration can become a reality. The pros and aims of a lunar base are discussed from the standpoint of military applications. The extensive use of manned space systems are foreseen as a prerequisite for large-scale lunar or lunar-Earth space operations.

A capability for planetary exploration is seen in the far future but no clear military application can now be predicted.

DEVELOPMENT REQUIREMENTS

A review of some developmental efforts that would help advance a military space program constituted the concluding portion of this study. A thorough knowledge must be acquired of the physical parameters of the environment in which space vehicles will operate. The component systems associated with space vehicles must be developed, with attention not only to subsystem performance, but also to integration into vehicle systems. Operational capability must be attained in many types of activity that are foreign to man's traditional experience near the Earth's surface. Personnel must be trained and procedures developed for space operations. It is not pretended that

Possible Functions for Man to Fulfill in Space

There appear to be many things for man to do in space. For some of these things, no automatic equipment is in sight. The functions that are examined are: (1) exploration, (2) experimentation, (3) fabrication, (4) maintenance, (5) resupply, (6) inspection and disabling of enemy systems, (7) surveillance and reconnaissance, (8) battle direction, (9) selection of countermeasures and counter-countermeasures, (10) terminal guidance of ground-launched weapons, (11) piloting, and (12) communication with other men. In most of those functions, men offer important advantages over fully automatic systems. When the missions are limited to orbits and trajectories near the earth, control of equipment in space by men on the ground offers an alternative approach that should be studied carefully. Difficulties of communication and control signaling must of course be considered. For missions into distant space, ground control is precluded by the transmission time delay.

PREREQUISITES FOR EFFECTIVE UTILIZATION OF MEN

What needs to be done in order to assure effective utilization of the capabilities inherent in men? The possibilities are usually discussed under the headings of selection, education and training, motivation, and human engineering of man-machine systems.

Selection

To offer a meaningful answer to the question, how much improvement in system performance can personnel selection yield, it is necessary to go in some detail into selection test characteristics and scales of measurement. Those subjects are discussed. It is concluded that it is highly worthwhile for the Air Force to continue to work diligently on personnel selection methods and to apply the most advanced techniques. Tests of aptitude for engineering and for piloting are especially important. The two aptitudes are by no means identical, and the Air Force is faced with such serious demands in both areas that the best possible selection procedures are needed. Research is needed also in the important area of selection for hazardous duty.

Training

The general requirement for training is discussed, and the advantages to be gained through the use of simulators is emphasized. In particular, part-task trainers are advocated. Part-task trainers can be designed in the form of teaching machines that motivate the trainee to practice and provide special training on critical phases of the mission.

NEEDED RESEARCH

Research is needed particularly in the following areas:

a. Specification and improvement of human performance capabilities and limitations as affected by education, training, and motivation and by environmental and combat conditions.

b. Specification and improvement of equipment performance capabilities and limitations as affected by advances in technology and by environmental and combat conditions.

c. Man-machine communication.

d. Measurement and specification of environmental and combat stresses.

e. Methodology of system design.

Human Performance

TAXONOMY. A better system of categories than is now available is needed as a framework for research on human capabilities and limitations, for design of man-machine systems, and for selection and training of personnel. Support of work on this problem is strongly recommended.

MEASUREMENT OF HUMAN PERFORMANCE. Measurements should be made to provide quantitative specifications of human capabilities in the main functions or operations that comprise the taxonomic system. The specification should be given in terms compatible with those used in describing the behavior of equipment components with which human operators may be associated. The number and selection of subjects for the measurements should be determined by the requirement that the data be useful in setting standards for personnel selection.

SELECTION AND TRAINING. The main need for research in the field of selection focuses on the problem of how best to use existing measures and measurement techniques to predict performance capability after extensive training. In training, research is needed on: (1) how to develop and maintain proficiency in remote control (e.g., manipulation via radio link); diagnosis of complex situations, and decision making; (2) how to improve and utilize part-task simulators and teaching machines; and (3) how to incorporate maintenance-of-proficiency features into weapon and support systems.

Chapter 12

RECONNAISSANCE AND INTELLIGENCE

There are two principle missions for reconnaissance as it exists today and in the foreseeable future. The first is related to general war. The second occurs before and during a limited war situation where the local area commander must receive the tactical intelligence necessary to gain a decision.

The most important phase of the first mission occurs during the cold war preliminaries, during which our national policy is aimed at the prevention of actual hostilities. In this period, reconnaissance must continually provide a high order of intelligence data on the entire spectrum of the enemy's war-making potential, his present and future intent, and an assessment of the probability that a surprise attack may be launched. It must provide the necessary target information to permit effective retaliation, or threat of retaliation, by the United States, and the knowledge of the enemy's air and electronic defense needed in carrying out such retaliation.

In the appraisal of war-making potential, it is important to determine the enemy's nuclear delivery capabilities, both overt and clandestine, together with his scientific and technical resources and readiness, both within and outside his country. Every effort must be made to gain technical intelligence regarding the characteristics of his military equipment, his performance of field tests, or any other information that would suggest the direction of his research and development.

Appraisal of the enemy's intent involves utilization of data from all available sources. Most of these sources are discussed in this report. One type of information which is vital in determining enemy intentions is the detection of movements of equipment, personnel, vehicles including aircraft, and any new construction or unusual preparations. The problem of surveillance of a territory like the USSR for such activity is so vast that the development of automatic aids for detecting change (which may be considered an automatic alarm concept) is deemed essential. Such equipment would conserve the effort of interpretive manpower by discarding redundant information and providing, essentially, automatic indication of "where to look."

Necessary targeting data involve recognition and identification of installations of all kinds, together with their location to the necessary accuracy. In an area so great as the Soviet territories, adequate recognition of targets can be beyond available manpower unless the "where to look" aid is provided as well. Here is where the combination of sensing devices can be so important. Electronic activity indicated by ferret methods, or heat sources detectable by infrared sensors, for example, can provide important indications of where detailed photography is required. Especially difficult problems will arise with concealed and remote military targets of the future such as missile complexes, whose recognition may be possible only during the building phases.

The accuracy required in targeting depends both upon the nature of the target, whether large or small, hard or soft, and upon the type of retaliatory attack. ICBM's require better geodetic accuracy for the target position than do manned bombers since no terminal course corrections are now made for long range rockets. Although ICBM requirements cannot be defined exactly, some limiting conditions can be established. For currently anticipated targets, the number of ICBM's required for a given task is fairly insensitive to target position errors (defined with respect to the launch site) if these are below 20 percent of the missile CEP. Currently, anticipated CEP's for Atlas and Titan are of the order of 2 miles. Future developments could refine guidance systems errors to somewhat less than one mile. In order to satisfy future demands, new geodetic surveys should provide accuracies of the order of 500 feet. This involves geodesy of the highest precision, and relates to an area, the Soviet territory, where even pioneer mapping of large portions is unavailable. [Fortunately, the reconnaissance satellite provides an excellent opportunity to perform such geodesy. This is discussed briefly below, in connection with recommendations on the 117L program, and in more detail in the full report of the committee.]

Recent history has shown that within the cold-war stalemate of the major powers, limited war engagements are likely. Reconnaissance problems associated with such hostilities are of a quite different type than those of the cold war situation — problems requirir quite different tools. In limited war, the reconnaissance mission is primarily to determine the disposition, capability, and intentions of an active military force within small but highly variable geographical bounds. The time scale is relatively short; military targets are generally small and mobile and may be available only at night. These considerations imply, therefore, a variety of reconnaissance techniques which have to be quick in response, all-weather versatile, and of high resolution.

The present review is intended neither to give a thorough analysis of the intelligence problems of the future nor to give a catalogue of equipments and methods for all possible situations which might be visualized. Its scope is limited to certain technical aspects of data collection methods for reconnaissance and intelligence, with emphasis on the operational contexts outlined above. A review of the current status and future promise of various detection devices is presented, and recommendations are made concerning future research and development when these seem justified. Because of the rather unique technical problems posed by future reconnaissance vehicles [especially artificial satellites,] detection problems cannot be considered independently of the vehicle and so special consideration was given to vehicles for reconnaissance.

Outlined below are some of the more important findings and recommendations of this study. The complete report considers these matters in much more detail, make additional specific recommendations, and provide supporting reasons for the conclusions.

PRINCIPAL RECOMMENDATIONS AND CONCLUSIONS

General Recommendations

a. SUPPORTING RESEARCH. It is essential to recognize that an alert reconnaissance and intelligence program must avail itself of continuous scientific assistance and must be in a state of continuous evolution. In order to make certain that interpretive techniques and procedures remain valid and useful, basic supporting research must be promoted in all fields related to reconnaissance objectives. Pressure must always be maintained to reduce the time elapsed between new scientific discoveries and their application to active reconnaissance work.

b. COMPONENT VERSUS SYSTEMS DEVELOPMENT. Too often a system design must be compromised because not enough time is allowed for the development of the basic detection component upon which it is based. Moreover, tying the development of new components to a system usually results in too much expensive hardware based on too little study and basic investigation. It is urged that detector development be supported vigorously for its own sake independent of any particular system. This principle is especially true in the areas of optical and infrared systems, but applies equally well to sonic and electromagnetic devices. The cost of such research is very small compared to costs of final systems.

c. NEW SYSTEMS VERSUS AVAILABLE SYSTEMS. It must be recognized that current reconnaissance can only be performed with available systems. Therefore, it is generally undesirable to discontinue further development of a successful system in favor of a potentially superior one with a long development lead time. Thus the committee feels it unrealistic, for example, to abandon continuous development and improvement of radar techniques even though it may appear that optical and infrared procedures will better answer some of the problems previously reserved for radar.

d. COMBINATION OF SENSORS. The limitations and capabilities of different collecting devices usually are so different that simultaneous use of two or more of them in one reconnaissance vehicle will greatly enhance system effectiveness.

e. TECHNICAL INTELLIGENCE AND THE SCIENTIFIC COMMUNITY. Because of the variety and specialized technical knowledge needed to interpret technical intelligence data and to suggest new methods for obtaining it, it is important that those agencies responsible for gathering intelligence be in close and continuing contact with competent people from the active scientific community. In the past, security requirements have inhibited such a healthy interchange.

Specific Recommendations

a. [ARTIFICIAL SATELLITE RECONNAISSANCE. The 117L program deserves every support, and it is recommended that effort on the present 117L photographic systems of both 6-inch and 36-inch focal length (sometimes referred to as "pioneer" and "advanced") be continued without diminution. The 6-inch system will provide, among other things, early and valuable experience in the difficult field of satellite photography. The 36-inch system can be an important step toward identification of installations.]

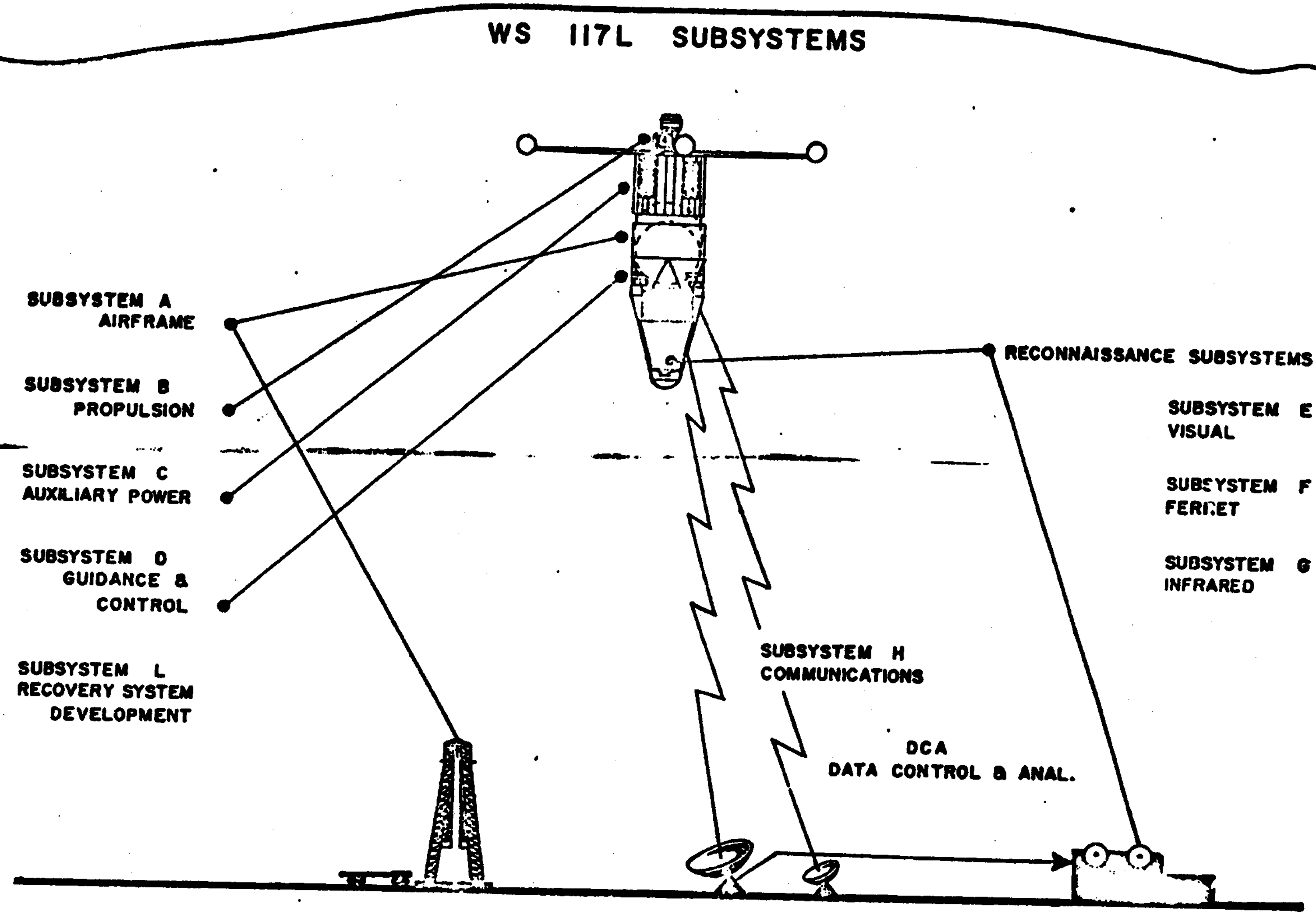

Figure 4. Conceptual drawing of WS 117L.

In addition, it is urged that there be added to the 117L program at the earliest possible date equipment to secure basic and precise geodetic mapping information. This should certainly be done before means are developed by the Soviets to deny us the use of satellites to gather this information. Precision geodetic mapping will involve:

(1) Intermittent frame cameras which are more suitable for precision map data than the slit cameras now planned.

(2) Simultaneous star field photographs which are possible from a satellite. These will provide attitude information necessary, in combination with orbital data, for precise geodesy in the absence of the usual ground control points.

(3) Careful re-evaluation of physical recovery of film as compared to data link transmission as the more practical way of obtaining precise mapping data without serious degradation.

b. TACTICAL RECONNAISSANCE (LIMITED WAR). An important need appears for very low altitude high speed aircraft, capable of carrying several reconnaissance sensors simultaneously. These include high resolution radar with moving target indication, ferret and intercept devices, photographic and infrared systems, and air sampling equipment. Such aircraft may or may not combine strike with reconnaissance, and depending in large part on this factor, will be manned or unmanned. They must be capable of operating from advanced bases (STOL or VTOL) and be as simple as consistent with their mission and reasonable chance of survival.

c. OPTICAL AND VISUAL METHODS. Optical methods using visible or near visible light, whether conventional photography or other sensors are employed, will continue to be dominant in collecting detailed reconnaissance information. Continued supporting research in this area, therefore, is essential. This should include the support of both theory and experiment in the design and fabrication of optical systems. Satellite applications emphasize the need for non-silver halide photographic systems which can be used in the presence of nuclear radiation.

In addition, since fine resolution photographs should be made at the lowest altitude which the Soviets or other potential enemies are unable to deny us, photography from aircraft above 100,000 feet is attractive for the near future, and effort should be made to improve aircraft for this purpose.

d. INFRARED DETECTION. Infrared offers many unique advantages in reconnaissance requiring an around-the-clock capability: for long range intelligence and early warning against missiles, and for heat mapping and object location. A long wavelength infrared picture or heat map deserves special emphasis. If made with equipment utilizing the wavelength region around 10μ, such a picture cannot only be made around the clock and through moderate overcasts, but also can provide an immediate indication of activity in many types of man-made installations. Combined with photographs of the same area, the heat picture can point out to a photo interpreter areas requiring detailed examination, and thus provide important "where to look" signals.

To utilize the full potentialities of infrared techniques, it is essential to provide increased support for research and development related to infrared technology, particularly in the development of detector components and in the development of image forming infrared sensors.

e. ELECTRONIC RECONNAISSANCE. It is felt that in this area satisfactory technical developments are already planned in an attempt to keep up with the sophistication of the electronic art. On the other hand, the lack of a coordinated national policy on the processing of this type of data causes much concern, as does similar lack of coordination in the handling of other forms of reconnaissance information.

f. RADAR DETECTION. Radar methods will continue to play an important role in future reconnaissance. The techniques for detecting nuclear blasts and ICBM takeoffs should be regarded as being in their infancy and, with improved methods, it may be possible to extend the detection range to multi-hop distances. For limited war situations, it is felt that there is a particular need for the development of an airborne, high-resolution radar. This radar need not have very long range, but should be adaptable for use with high speed, low altitude aircraft, and possess MTI capabilities.

g. ACOUSTIC DETECTION. Sonic propagation to extremely long ranges at relatively low frequencies is possible through an acoustic duct centered around 40 thousand feet. This remarkable phenomenon deserves a thorough experimental research program involving both balloon-carried receivers and large ground