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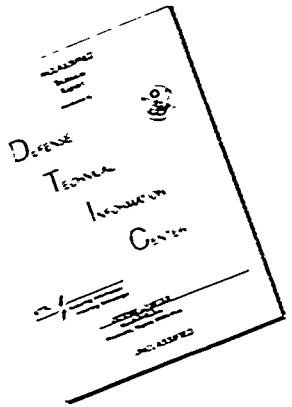

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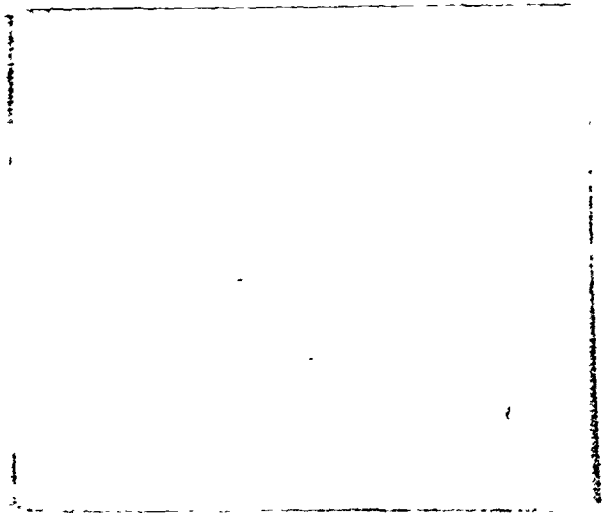

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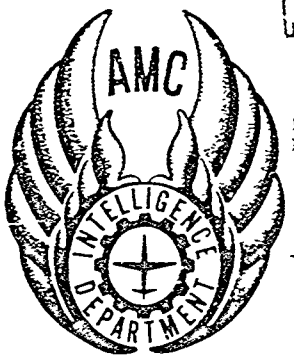

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[redacted]

Technical Report No. F-TS-[illegible]-RE

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Approved by:

[signature]
[redacted], Colonel, USA
Chief, Technical Intelligence Division
Intelligence Department

For the Commanding General:

[signature]
[redacted], Colonel, USAF
Chief, Intelligence Department

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ABSTRACT

A descriptive and analytical study of the unidentified aerial objects that have been reported both in the United States and from foreign countries is presented.

Individual cases are described in brief form as an appendix.

The analytical treatment of the subject is largely of a qualitative and generalized nature. However, detailed analyses and detailed results are presented where this procedure is possible, and will assist in establishing the validity or tenability of an overall hypothesis.

Project "Sign" is still largely characterized by the collection of data, without sufficient information to permit definite, specific conclusions to be made. No definite evidence is yet available to confirm or disprove the actual existence of unidentified flying objects as new and unknown types of aircraft. A limited number of the incidents have been identified as known objects.

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FOREWORD

Project "Sign" was initiated by the Technical Intelligence Division, Air Materiel Command, and assigned Project Number MX-304, 22 January 1948, under authority of a letter from the Deputy Chief of Staff, Materiel, USAF. This letter is referenced C/S, USAF, 30 December 1947, subject "Flying Disks."

Assistance in analyzing the reported observations has been provided by other Divisions of Air Materiel Command in accordance with Technical Instructions TI-2185, Addendum No. 3, dtd 11 February 1949, subject: "Project Sign" - Evaluation of Unidentified Flying Objects".

Analysis of the reported incidents, as an effort to identify astro-physical phenomena, is being accomplished by Ohio State University under contract with Air Materiel Command.

A special study has been initiated with the Rand Project in accordance with Air Corps Letter No. 80-10 dtd 21 July 1948 to present information that would serve to evaluate the remote possibility that some of the observed objects may be space ships or satellite vehicles.

Members of the Scientific Advisory Board to the Chief of Staff, USAF, have also supplied their services in a consulting capacity.

[redacted]

INTRODUCTION

This report is written to present the status of work being accomplished on Project "Sign", to summarize the data collected on sightings of unidentified aerial objects, to review the methods and reasoning applied in the evaluation of the data, and to present the results so far obtained from the study of data available.

It is not expected that this report can present a final estimate of the situation regarding all the incidents reported. The data is still being studied by specialists in the fields of astrophysics and psychology, and further information is being collected to enable personnel evaluating project "Sign" incidents to determine possible explanations of some of the sightings. However, the report will furnish information on the present state of the investigation to staff personnel in this headquarters and in higher echelons, and to others who are required to assess the possibility of a threat to national security presented by the sightings of such large numbers of unidentified flying objects.

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SECRET

SUMMARY

The results of the study reviewed in this report are based on data derived from reports of 243 domestic and thirty (30) foreign incidents. Data from these incidents is being summarized, reproduced and distributed to agencies and individuals cooperating in the analysis and evaluation. Distribution has so far been accomplished on the summaries of 160 incidents and more are in process of reproduction at this time.

A check list of items to be noted in reporting incidents has been prepared and distributed to government investigative agencies. The data obtained in reports received are studied in relation to many factors such as guided missile research activity, weather and other atmospheric sounding balloon launchings, commercial and military aircraft flights, flights of migratory birds, and other considerations, to determine possible explanations for sightings.

Based on the possibility that the objects are really unidentified and unconventional types of aircraft a technical analysis is made of some of the reports to determine the aerodynamic, propulsion, and control features that would be required for the object to perform as described in the reports. The objects sighted have been grouped into four classifications according to configuration:

1. Flying disks, i.e., very low aspect ratio aircraft.
2. Torpedo or cigar shaped bodies with no wings or fins visible in flight.
3. Spherical or balloon-shaped objects.
4. Balls of light

The first three groups are capable of flight by aerodynamic or aerostatic means and can be propelled and controlled by methods known to aeronautical designers. The fourth appears to have no physical form attached, but the means of support may not have been seen by the observer.

Approximately [illegible] percent of the incidents have been identified as conventional aerial objects to the satisfaction of personnel assigned to Project "Sign" in this Command. It is expected that a study of the incidents in relation to weather and other atmospheric sounding balloons will provide solutions for an equivalent number. Verbal statements by an astro-physicist at Ohio State University and by psychologists of the Aero-Medical Laboratory of this Command, indicate the possibility of solving an appreciable number of the sightings as a result of their investigations. Elimination of incidents with reasonably satisfactory explanations will clarify the problem presented by a project of this nature.

The possibility that some of the incidents may represent technical developments far in advance of knowledge available to engineers and scientists of this country has been considered. No facts are available to personnel at this Command that will permit an objective assessment of this possibility. All information so far presented on the possible existence of space ships from another planet or of aircraft propelled by an advanced type of atomic power plant have been largely conjecture. Based on experience with nuclear power plant research in this country, the existence on Earth of such engines of small enough size and weight to have powered the objects described is highly improbable.

Reports of unidentified flying objects are not peculiar to the present time. In, "The Books of Charles Fort" by Tiffany Taylor, published in 1941 by Henry Holt & Co., New York, similar phenomena are described as having been sighted during past centuries. In the last war, numerous sightings of "balls of fire" in the air were reported by bomber crews.

CONCLUSIONS

No definite and conclusive evidence is yet available that would prove or disprove the existence of these unidentified objects as real aircraft of unknown and unconventional configuration. It is unlikely that positive proof of their existence will be obtained without examination of the remains of crashed objects. Proof of non-existence is equally impossible to obtain unless a reasonable and convincing explanation is determined for each incident.

Many sightings by qualified and apparently reliable witnesses have been reported. However, each incident has unsatisfactory features, such as shortness of time under observation, distance from observer, vagueness of description or photographs, inconsistencies between individual observers, and lack of descriptive data, that prevents definite conclusions being drawn. Explanations, of some of the incidents revealed the existence of simple and easily understandable causes, so that there is the possibility that enough incidents can be solved to eliminate or greatly reduce the mystery associated with these occurrences.

Evaluation of reports of unidentified objects is a necessary activity of military intelligence agencies. Such sightings are inevitable, and under wartime conditions rapid and convincing solutions of such occurrences are necessary to maintain morale of military and civilian personnel. In this respect, it is considered that the establishment of procedures and training of personnel is in itself worth the effort expended on this project.

RECOMMENDATIONS

Future activity on this project should be carried on at the minimum level necessary to record, summarize, and evaluate the data received on future reports and to complete the specialized investigations now in progress. When and if a sufficient number of incidents are solved to indicate that these sightings do not represent a threat to the security of the nation, the assignment of special project status to the activity could be terminated. Future investigations of reports would then be handled on a routine basis like any other intelligence work.

Reporting agencies should be impressed with the necessity for getting more factual evidence on sightings, such as photographs, physical evidence, radar sightings, and data on size and shape. Personnel sighting such objects should enlist the assistance of others, when possible, to get more definite data. For example, military pilots should notify neighboring bases by radio of the presence and direction of flight of an unidentified object so that other observers, in flight or on the ground, could assist in its identification.

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DISCUSSION

Organization of Data on Incidents

Approximately 243 domestic incidents have been received, at the present time. In each incident, the observers have been interrogated by investigators and the results have been analyzed by technical personnel.

Condensed summaries have been prepared for the list of incidents in sufficient quantity to make the basic information easily available to individuals or agencies having an authority or an interest in the project. (See Appendix A).

A detailed check list, compiled by technical personnel, indicating the basic elements of information, necessary for analysis of the individual incident, has been prepared and distributed to appropriate government agencies.

In order to identify ordinary and conventional objects, that have probably been included in the list of reported incidents, graphical methods have been applied, so as to present the basic data in such form that overall facts, implicit in the grouped data, will be made apparent. (See Appendix B).

The prepared graphical data includes:

(a) Charts concerning unidentified aerial objects, to indicate:

1. Type of object observed
2. Vicinity in which particular type of object was observed
3. Direction of flight

(b) Locations of guided missiles, research and related centers

(c) Locations of airlines, airfields, both military and commercial.

(d) Locations of radio beacon stations

(e) Known or projected radar stations from which reports and assistance may be derived

(f) Meteorological stations from which balloon release data, radiosonde or theodolite readings may be obtained

(g) Past, current and projected celestial phenomena

(h) Flight paths of migratory birds

Psychological Analysis

A psychological analysis of the reported data is being prepared by Aero-medical Laboratory, A.M.C., for the purpose of determining those incidents that are probably based upon errors of the human mind and senses. A preliminary verbal report from the professional psychologists indicates that a considerable number of incidents can be explained as ordinary occurrences that have been misrepresented, as the result of human errors.

The condition of "vertigo", well known to airplane pilots, as well as others, is considered to be an important factor in some of the reported incidents. "Vertigo" is defined from a medical viewpoint by Webster's Dictionary as "Dizziness or swimming of the head; a disturbance in which objects, though stationary, appear to move in various directions, and the person affected finds it difficult to maintain an erect posture. It may result from changes in the blood supply of the brain or from disease of the blood, eyes, ears, stomach, or other organs."

Accelerations, resulting from airplane maneuvers, together with space-orientation difficulties at night in an airplane, due to the lack of or strangeness of visual references, makes a condition of "vertigo" more likely to appear in personnel in night-flying aircraft than under more normal conditions. The fact that both pilot and co-pilot may report the same impressions is not complete proof of accuracy, since both individuals have experienced the same maneuvers and accelerations and have viewed the same lights and surroundings under the same optical conditions (including the same windshield and canopy glass).

A more complete discussion of psychological factors is expected to be provided in a future status report. Quite probably, some of the incidents of fast, highly maneuvering "lights", reported by both air and ground observers, are the result of "vertigo" or optical illusions.

Strictly speaking, no engineering analysis of an incident should be initiated until the psychological analysis has been made and has shown that psychological factors cannot explain the observation.

Agencies, Outside Air Material Command, Supplying Information and Analysis

Specialist services, supplementary to those of Air Material Command technical offices, are being provided by a number of agencies.

The Air Weather Service has reviewed the list of incidents and has provided the information that twenty-four of them coincide, both with respect to location and time, with the release of weather balloons.

The Ohio State University has contracted with Air Material Command to supply astronomical services in an effort to identify meteors, planetoids and associated phenomena. Professor Hynek, Ohio State University Astro-Physicist and Head of the University Observatory has undertaken to review the incident summary sheets. While this work has not yet been completed, Professor Hynek has reported verbally that he is satisfied that a number of the reported observations represent astro-physical phenomena.

Members of the Scientific Advisory Board to the Chief of Staff, USAF, who have provided consultant services to Project "Sign", include Dr. Irving Langmuir, Chief, General Electric Research and Dr. G. E. Valley of MIT.

A preliminary type of interview has been held between Dr. Langmuir and personnel of Project "Sign" during early stages of the project. It is intended to consult further with Dr. Langmuir in an effort to supplement present technical efforts toward identifying the reported objects.

Dr. G. E. Valley has displayed an active interest in Project "Sign", to the extent of reviewing the reported incidents and writing an overall type of analysis in which he groups the various objects and then analyzes each group from the standpoint of scientific feasibility. This analysis is provided as Appendix (C) to this report.

Inasmuch as various surmises have been advanced that some of the reported observations may have represented "space ships" or satellite vehicles, a special study has been initiated with the Rand Corporation, under the Rand Project, to provide an analysis from this standpoint and also to provide fundamental information, pertaining to the basic design and performance characteristics that might distinguish a possible "space ship."

As a preliminary undertaking, the Rand Project has submitted a study by Dr. Lipp in which the possibility is explored of any planet in the known universe being in a physical and cultural position to allow the development and use of the "space ship". This study has been prepared in the form of a report that is presented as Appendix (D).

The Weather Bureau Library of the Department of Commerce has supplied information on "ball lightning". This was requested because of the belief by some persons that some of the observations may have represented "ball lightning". It appears that the subject of "ball lightning" occupies an undetermined status and authorities are not at all convinced that such a phenomena actually exists.

The Federal Bureau of Investigation has assisted Project "Sign" in a number of instances, both by investigations of the character and reliability of witnesses of incidents and by providing other investigative services.

Considerations Affecting Analysis and Evaluation

OPERATIONAL

Inasmuch as there is a distinct possibility that a number of the reported incidents represent domestic projects of a security-classified nature, the list of incidents has been submitted to higher echelons for review.

Since weather balloons, blimps, airplanes of unusual size or configuration, and guided missiles test vehicles may represent some of the observations, action has been taken to obtain information, concerning schedules and flights of such craft from the appropriate agencies.

In connection with the psychological studies being performed, extensive investigations, concerning the character and reliability of the reporting witnesses have been made.

TECHNICAL

A certain proportion of incidents appear to be real aircraft, though of unconventional configuration. In order to investigate the credibility of their existence the following factors must be considered in any technical analysis.

Aircraft

Method of Support (Lift)

- Wings
- Fuselage Lift (Wingless)
- Rotor
- Vertical Jet
- Magnus Effect (rotating cylinder, cone or sphere, subjected to relative translational air velocity)
- Aerostatic (lighter-than-air craft)

Method of Propulsion (Thrust)

- Propeller-reciprocating engine combination
- Jet, rocket, ramjet (utilizing conventional fuels and oxidants or possibly atomic energy)
- Aerodynamic (Katzmayer Effect - oscillating airfoils developing negative drag (thrust)

If an atomic energy powered engine were available, a small mass flow at a large velocity could accomplish the required lift and propulsive forces and the large energy expenditure will be of small importance.

However, the heat exchange requirements for the atomic powered engine appear to demand physical dimensions of prohibitive size that presently would preclude the use of this powerplant for aircraft.

In addition, manned aircraft would require an excessive percent weight of shielding for human protection, unless configurations of extremely large size were used. If unshielded craft were in operation, existing detection means would probably have indicated their presence.

Metallurgical limitations to date, limit the rate of conversion the heat energy of the atomic source to useful propulsive work to such an ineffective order of magnitude that such a power system is quite unlikely from the standpoint of size and weight.

Stability

Aerodynamic (both static and dynamic through the use of aerodynamic surfaces and weight distribution).

Servo-mechanism (gyro or accelerometer - servo-motor system)

Control

Movable surfaces in airflow or jet

Jet (flow control or swiveling types).

Possible Spaceships

World knowledge, techniques, and resources are considered to be presently adequate for the development of spaceships.

Distinguishing design and performance parameters are expected to be supplied as a special study by the Rand Project.

Probable Natural Phenomena

Astrophysical (meteors, comets, planetoids, etc.) Astrophysical analysis is expected to be performed by personnel of Ohio State University Research Foundation.

Electromagnetic (ball lightning, St. Elmo's Fire, Phosphorescence, corona, etc.).

Ordnance Items

While this analysis considers the reported objects largely from the standpoint of aircraft with requirements for speed and substantial duration of flight and range, it is entirely possible that the configurations reported in small sizes could serve as very useful ordnance items to take the place of (or supplement) such short-range weapons of ground (infantry) warfare as the trench mortar, hand grenade, etc.. The small saucer-like, spinning,

disks, reportedly under development by the USSR with the aid of German Scientists, having explosive edges and launched by a compressed air catapult, (perhaps in the manner of clay pigeons projected by a trap mechanism) could possibly be ordnance articles. Also, such devices could be used by aircraft in attacking enemy airplane formations. In such cases, only a modest speed, short range, and limited flight duration would be required, hence the aerodynamic efficiency of the design would not be of very much importance.

Insufficient Information for Even Possible or Hypothetical Type Determination.

Discredited Reports

Erroneous (See Discussion, Psychological Errors)

False

Technical Analysis of Various Configurations

The extreme lack of data for each of the incidents that have been reported makes it presently impossible to accurately identify any of the reported craft with respect to design and performance. Technical analysis must be made by considering possibilities and probabilities, which are expected to be proved or disproved only when complete data or physical specimens of aircraft (crash) are available. Unidentified aerial objects appear to be grouped as follows:

(1) Flying disks (saucers)
(2) Torpedo or Cigar Shaped Bodies (no wings or fins visible in flight)
(3) Spherical or Balloon-Shape Objects (capable of hovering descending, ascending or travelling at high speed).
(4) Balls of light (no apparent physical form attached), Capable of maneuvering, climbing, and travelling at high speed.

The first three groups of objects are capable of flight through the atmosphere by means of aerodynamic and propulsion designs (to produce the required lift and thrust) that are readily conceivable by aeronautical designers. The stabilizing and control features that would be required, while more obscure, could conceivably be provided. The question arises, however, as to whether these configurations would develop much speed and allow a sufficient duration of flight and adequate range to be of practical use as aircraft.

Flying Disks

The disk or circular planform has not been used in representative aircraft, either military or civilian, for the reason that the induced drag, as determined by the Prandtl theory of lift, would

apparently be excessively high, since the aspect ratio of a circular planform is only 1.27. Extension of the Prandtl theory, has also shown that the maximum possible lift coefficient to be expected from such low aspect ratio planforms should also be poor. In addition, the relatively large mean aerodynamic chord would present difficult design problems, to achieve static longitudinal stability for airfoil sections having a significant center-of-pressure travel, or for airfoil sections of so-called "stable" type, when equipped with ailerons at the trailing edge.

In the very low aspect ratio range, the Prandtl theory is probably very inaccurate. Wind-tunnel tests of very low aspect ratio airfoils indicate much less induced drag increase than expected from theory and also demonstrate very high maximum lift coefficient accompanied by extremely high stalling angles. However, in general the induced drag of very low aspect ratio wings is much larger than the induced drag of conventional aircraft wings, a condition which would adversely affect all performance values in flight conditions which require medium and high lift coefficients. Thus, performance in climb, at altitude, and for long-range conditions would be relatively poor, although high speed would be little affected.

Notwithstanding the predicted aerodynamic disadvantages of circular planform wings, quite a number of experimental efforts have been made to use this configuration - and not all of them by persons ignorant of aerodynamic fundamentals. Experimental wind-tunnel work at the NACA (1933) showed both maximum lift coefficients and stall characteristics much more favorable than could be anticipated.

The problem of static longitudinal stability could possibly, be solved by the use of a stable airfoil section of the reflexed trailing edge type with wing tip ailerons (perhaps floating) aerodynamically independent of the wing.

At supersonic speeds, where the induced drag is small, the circular planform offers the probability of reduced drag, characteristic of low aspect ratio airfoils in the supersonic range. Also the circular planform presents a swept-back leading edge (of variable sweep along the span), which should result in a reduced effective Mach Number, with attendant reduced drag for a certain supersonic speed range.

No definite information has been received on the method of propulsion used on flying disks which have been sighted. However, because of distance factors involved in the sightings it is quite possible that either propellers or jet propulsion could have been employed without being noted by the observer.

Flying Fuselages (Torpedo or Cigar-Shaped Body)

While the cigar or torpedo-shaped body represents an efficient form for the fuselage of an airplane or the body of a guided missile,

in neither case has it been used as a primary lift-producing surface. However, an extension of the Prandtl theory of lift indicates that a fuselage of the dimensions reported by the Eastern Airlines pilots Whited and Chiles in the Montgomery, Alabama, incident could support a load comparable to the weight of an aircraft of this size at flying speeds in the subsonic range. The Prandtl theory probably gives very conservative values of maximum lift for bodies of this shape. German experience indicates that the maximum lift may be twice as high as that given by the theory.

Although the craft sighted by Whited and Chiles was reported to be without wings and fins, it is possible that it could have been equipped with extensible wings for take-off and landing, contained within the fuselage in cruising flight.

This type of aircraft could also be partially supported in the take-off and landing condition by the vertical component of the jet thrust, if the landing and take-off took place with the fuselage axis, or the jet stream direction in a vertical or nearly vertical altitude. The further possibility that an extensible rotor, concealed within the fuselage, could have been used, would provide another method for landing and take-off that would allow wingless flight at very high speed. Such a design could result in a relatively large duration of flight and corresponding range.

While no stabilizing fins were apparent on the "flying fuselage" reported by Whited and Chiles, it is possible that vanes within the jet, operated by a gyro-servo system could have provided static stability, longitudinally, directionally and laterally. The same vanes could also have been used for accomplishing static balance or trim, as well as control for maneuvering.

The above discussion regarding weight, controllability, stability, etc. is not intended to represent deductions regarding the exact nature of the torpedo or cigar-shaped aircraft which were sighted by the airline pilots, Whited and Chiles, and others. They are merely statements of possibilities, which are intended to show that such an aircraft could support and control itself by aerodynamic means.

The propulsive system of this type of vehicle would appear to be a jet or rocket engine. The specific fuel consumption of engines to this type would be rather high. This, coupled with the fact that aerodynamic lift on such a body would be accompanied by high drag, places a serious limitation on the range of this aircraft for any particular gross weight. If this type of unidentified aerial object has extremely long range, it is probable that the method of propulsion is one which is far in advance of presently known engines.

Round Objects (Spherical and Balloon-Shaped Objects)

Spherical or balloon-shaped objects, are not usually considered as efficient aircraft. Not only would the drag of such bodies be high, but the energy expenditure that would be required to develop lift by aerodynamic means would be excessive. The only conceivable

means of producing lift for such a body, other than by aerostatic (simple buoyancy) means, would be by rotation of the sphere with translational motion relative to the air; or by discharging a stream of air vertically downward. Aerodynamic flight could be accomplished with a rotating sphere, provided the detailed design problems, including stability and control were worked out. The methods, using a blower system or jets, would require relatively greater amounts of energy and while they could be used for flights of very short range and duration, would not ordinarily be considered as practical by aeronautical designers.

The obvious explanation for most of the spherical shaped objects is that they are meteorological or similar type balloons. This, however, does not explain reports that they travel at high speed or maneuver rapidly. It is possible that the movement of the objects was some kind of an optical illusion, or that movement for a brief period due to a gas leak in the balloon was exaggerated by observers.

Balls of Light

No reasonable hypothesis of the true nature of balls of light, such as that reported by Lt. Gorman at Fargo, N. Dakota, has been developed that explains the behavior reported. The most reasonable explanation is that the lights were suspended from balloons, or other means of support, not visible at night, and the violent maneuvers reported are due to illusion.

Possibility of Scientific Developments in Advance of Knowledge in this Country.

Consideration has been given to the possibility that these unidentified aircraft represent scientific developments beyond the level of knowledge attained in this country. Since this is probably the most advanced of the industrial nations on the earth, and our interest in scientific developments throughout the world is very active, it would be necessary for any other country to conduct research and development work in extreme secrecy for any such project to have reached such an advanced state of development without a hint of its existence becoming known here. The only nation on earth with extensive technical resources which has such rigid security, is the U.S.S.R. An objective evaluation of the ability of the Soviets to produce technical developments so far in advance of the rest of the world results in the conclusion that the possibility is extremely remote. Most of the successful Soviet aeronautical developments have been produced by utilizing experience of other nations, some of them being very close copies, so it is very unlikely that they have developed the propulsion and controldevices necessary to make these objects perform as described.

Another possibility is that these aerial objects are visitors from another planet. Little is known of the probabilities of life on other planets, so there is no basis on which to judge the possibility that civilizations far in advance of ours exist outside the earth. The commentary on this possibility by Dr. James Lipp of the Sand Project in Appendix D, indicates that this solution of the mystery connected with the sightings of unidentified flying

objects is extremely improbable. Pending elimination of all other solutions or definite proof of the nature of these objects, this possibility will not be further explored.

APPENDIX "A"

Distribution of Incident Summaries:

Air Material Command

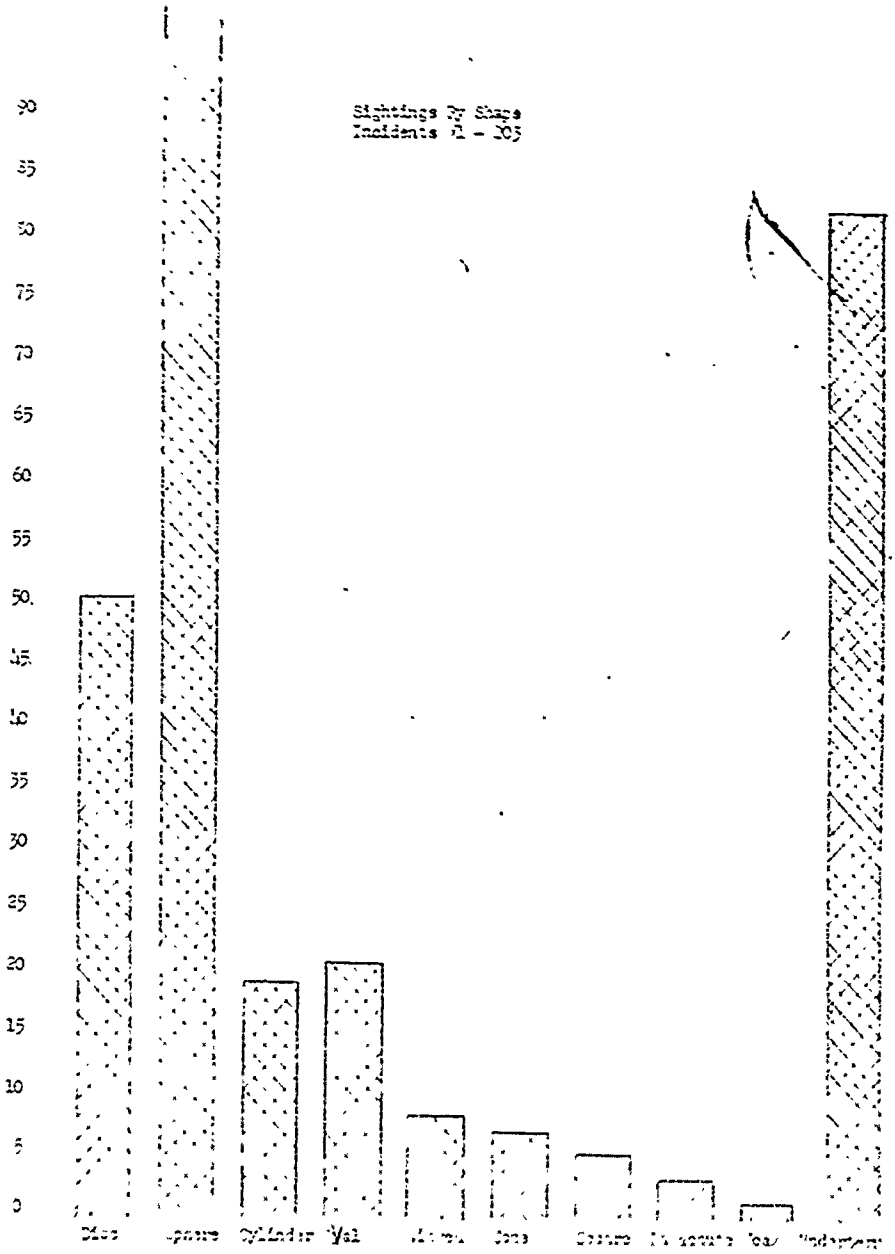
Aero Medical Laboratory (MCRFXD)
Weather Liaison (MCLAAS)
Research and Development (MCRTOS)
Electronic Plans (MCPSEP)
Technical Intelligence, Technical Sections (MCI)

Other Agencies

Directorate of Intelligence, Hq., USAF (AFOIN)
Office of Naval Intelligence (ONI)
Cambridge Field Station, Cambridge, Mass.
Air Weather Services, Andrews AFB, Washington, D. C.
Ohio State University, Dr. Hynek
Rand Corp., Rand Project (USAF)
Scientific Advisory Board (USAF) Dr. Valley

3-11750

"APPENDIX B"


Sightings By Shape
Incidents 71 - 205
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0

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"Ufo Shapes Incidents 1-235
Intensity of Sightings - By Date

S-11750

Disc Shapes – Incidents – 1-235
Intensity of Sightings – By Date

S-11750

Ball Shape Incidents 1-253
Intensity of Sightings by Date

3-11789

Miscellaneous Shapes (Other than Ball, Disc & Undetermined)
Incidents 1-235
Intensity of Sightings - By Date

Undetermined Shapes – Incidents 1-233
Intensity of Sightings – By Date

S-11703

APPENDIX "D"

Some Considerations Affecting the Interpretation of Reports of Unidentified Flying Objects

By

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The writer has studied summary abstracts and comments pertaining to unidentified flying objects, which were forwarded by Air Force Intelligence. These remarks are divided into three main parts: the first part is a short summary of the reports: the second part consists of a general survey of various possibilities of accounting for the reports: the third part contains certain recommendations for future action.

PART I -- SHORT SUMMARY OF OBSERVATIONS

The reports can be grouped as follows:

Group 1 -- The most numerous reports indicate the daytime observation of metallic disk-like objects, roughly in diameter ten times their thickness. There is some suggestion that the cross section is asymmetrical and rather like a turtle shell. Reports agree that these objects are capable of high acceleration and velocity: they often are sighted in groups, sometimes in formation. Sometimes they flutter.

Group 2 -- The second group consists of reports of lights observed at night. These are also capable of high speed and acceleration. They are less commonly seen in groups. They usually appear to be sharply defined luminous objects.

Group 3 -- The third group consists of reports of various kinds of rockets, in general appearing somewhat like V-2 rockets.

Group 4 -- The fourth group contains reports of various devices which, in the writer's opinion, are sounding balloons of unusual shape such as one sold by the General Mills Company to Navy contract.

Group 5 -- The fifth group includes reports of objects in which little credence can be placed.

General Remarks

In general, it is noted that few, if any, reports indicate that the observed objects give any noise or radio interference. Nor are there many indications of any material effects or physical damage attributable to the observed objects.

Summary -- PART I

This report will consider mainly the reports of Groups 1 and 2.

PART II -- IN POSSIBLE EXPLANATIONS OF THE REPORTS

Section A -- What can be deduced concerning the nature of an unknown aerial object from a single sighting?

Here, there are two problems: first, how much can be deduced concerning the nature of the objects from geometrical calculations alone; second, how much more can be deduced if, in addition, it is assumed that the objects obey the laws of nature as we know them.

Concerning the first problem, it can be stated that only ratios of lengths, and rates of change of such ratios, can be accurately determined. Thus, the range and size of such objects cannot be determined; and it is noticeable that reports of size of the observed objects are widely at variance. However, angles, such as the angle subtended by the object, can be observed. Likewise there is fair agreement among several observers that the diameter of the objects of Group 1 is about ten times their thickness. Although velocity cannot be determined, angular velocity can be, and in particular the flutter frequency could, in principle, be determined.

All that can be concluded about the range and size of the objects, from geometrical considerations alone, is: 1) from the fact that estimated sizes vary so widely, the objects were actually either of different sizes, or more likely, that they were far enough from the observers so that binocular vision ceased to stereoscopic effect: this only means that they were farther off than about thirty feet; 2) since objects were seen to disappear behind trees, buildings, clouds, etc., they are large enough to be visible at the ranges of those recognizable objects.

Now, it is particularly of prime importance to estimate the size and mass of the observed objects. This may be possible to some extent if it is reasonable to assume that they obey the laws of physics. Since the objects have not been observed

to produce any physical effects, other than the one case in which a ship was encountered along the trajectory, it is not certain that the laws of mechanics, for instance, would be sufficient.

But suppose that mechanical laws alone are sufficient, then the following example is sufficient proof that at least a length could, in principle, be determined: suppose a simple pendulum were observed suspended in the sky; then after observing its frequency of oscillation, we could deduce from the laws of mechanics its precise length.

This suggests that something could be deduced from the observed fluttering motion of some of the objects of Group 1. Assume that we know the angular frequency and angular amplitude of this fluttering motion (they can be measured in principle from a motion picture). Then for purposes of calculation assume the object to be thirty feet in diameter, to be as rigid as a normal aircraft wing of 30-foot span, to be constructed of material of the optimum weight-strength ratio and to be a structure of most efficient design. It is now possible to calculate how heavy the object must be merely to remain rigid under the observed angular motion. Let the calculation be made for a plurality of assumed sizes 1, 2, 4, 8, 16, 32, 64 ----- up to say 200 feet, and let calculated mass be plotted versus assumed size. The non-linear character of the curve should indicate an approximate upper limit to the size of the object.

If, in addition, it is assumed that the flutter is due to aerodynamic forces, it is possible that more precise information could be obtained.

The required angular data can probably be extracted from witnesses most reliably by the use of a demonstration model which can be made to oscillate or flutter in a known way.

Summary -- PART II, Section A

Geometrical calculations alone cannot yield the size of objects observed from a single station; such observation together with the assumption that the objects are essentially aircraft, can be used to get reasonable limits of size.

Section B -- The possibility of supporting and propelling a solid object by unusual means.

Since some observers have obviously colored their reports with talk of rays, jets, beams, space-ships, and the like, it is well to examine what possibilities exist along these lines. This is also important in view of the conclusions of PART II, Section A, of this report.

Method I -- "Propulsion" or support by means of "rays" or "beams".

By "rays" or "beams" are meant either purely electromagnetic radiation or else radiation which is largely corpuscular like cathode-rays or cosmic-rays or cyclotron-beams.

Now, it is obvious that any device operating or supported by such means is fundamentally a reaction device. It is fundamental in the theory of such devices that a given amount of energy is most efficiently spent if the momentum thrown back or lost is large. This means that a large mass should be given a small acceleration -- a theorem well understood by helicopter designers.

The beams or rays mentioned do the contrary, a small mass is given a very high velocity, consequently enormous powers, greater than the total world's power capacity, would be needed to support even the smallest object by such means.

Method II -- Direct Use of Earth's Magnetic Field

One observer (Incident 68) noticed a violent motion of a hand-held compass. If we assume from this that the object produced a magnetic field, comparable with the Earth's field; namely, 0.1 gauss, and that the observer found that the object subtended an angle θ at his position, then the ampere-turns of the required electromagnet is given by:

$$ni = \frac{10R}{\theta^2} \quad \text{where } R \text{ is the range of the object.}$$

For instance, if R is one kilometer and the object is 10 meters in diameter, then ni = 1 billion ampere-turns.

Now, if the object were actually only 10 meters away and were correspondingly smaller; namely, 10 cm in diameter, it would still require 10 million ampere-turns.

These figures are a little in excess of what can be conveniently used on the ground. They make it seem unlikely that the effect was actually observed.

Now, the Earth's magnetic field could exert on such a magnet or device not only a torque but also a force. The force depends not linearly on the Earth's field intensity but on its inhomogeneity or gradient. This force is about only strong enough to change the field over a distance of 10 meters (assumed size of the object) is scarcely measurable, therefore the gradient is not practicable for a drive due to local anomalies. Even, even if the effect were large enough to use, it would still be completely impracticable.

Method III -- Support of an electrically charged object by an effort to move perpendicular to the Earth's magnetic field

A negatively charged body moving from west to east, or a positively charged body moving from east to west will experience an upward force due to the earth's magnetic field.

A sphere 10 meters diameter moving at a speed of one kilometer second would experience an upward force of one pound at the equator if charged to a potential of 5×10^{-12} volts. This is obviously ridiculous.

Section B -- The anti gravity shield

It has been proposed, by various writers, perhaps first by H. G. Wells, that it might be possible to construct a means of shielding a massive body from the influence of gravity. Such an object would then float. Recently, there appeared in the press a notice that a prominent economist has offered to support research in such an enterprise.

Obviously, conservation of energy demands that considerable energy be given the supported object in order to place it on the shield. However, this amount of energy is in no way prohibitive, and furthermore it can be gotten back when the object lands.

Aside from the fact that we have no suggestions as to how such a device is to be made, the various theories of general relativity all agree in assuming that gravitational force and force due to acceleration are indistinguishable, and from this assumption the theories predict certain effects which are in fact observed. The assumption, therefore, is probably correct, and a corollary of it is essentially that only by means of an acceleration can gravity be counteracted. This, we can successfully do for instance by making an artificial satellite, but this presumably is not what has been observed.

Summary -- Part II, Section B

Several theoretical means of supporting or propelling a solid object have been considered, all are impracticable. This finding lends credence to the tentative proposed assumption of Part II, that the objects are supported and propelled by some normal means, or else that they are not solids. No discussion of the plan of Part II, Section B, can, in principle, of course, be complete.

Section C -- Possible causes for the reports

Classification I -- Natural terrestrial phenomena

.. the observation may be .. to some effect such as

ball lightning. The writer has no suggestions on this essentially meteorological subject.

2. The objects may be some kind of animal.

Even in the celebrated case of Incident 170 where the light was chased by a P51 for half an hour and which was reported by the pilot to be intelligently directed, we can make this remark. For considering that an intelligence capable of making so remarkable device would not be likely to play around in so idle a manner as described by the pilot.

In this connection, it would be well to examine if some of the lights observed at night were not fire-flies.

3. The observed objects may be hallucinatory or psychological in origin. It is of prime importance to study this possibility because we can learn from it something of the character of the population: its response under attack; and also something about the reliability of visual observation.

One would like to assume that the positions held by many of the reported observers guarantee their observations. Unfortunately, there were many reports of curious phenomena by pilots during the war -- the incident of the fire-ball fighters comes to mind. Further, mariners have been reporting sea-serpents for hundreds of years yet no one has yet produced a photograph.

It would be interesting to tabulate the responses to see how reliable were the reports of the Japanese balloons during the war. There we had a phenomenon proven to be real.

It is interesting that the reports swiftly reach a maximum frequency during the end of June 1947 and then slowly taper off. We can assume that this is actually an indication of how many objects were actually about, or, quite differently, we can take this frequency curve as indicating something about mass psychology.

This point can be tested. Suppose the population is momentarily excited: how does the frequency of reports vary with time? A study of crank letters received after the recent curiosity given to the satellite program should give the required frequency distribution.

It is probably necessary but certainly not sufficient that the unidentified-object curve and the crank-letter curve should be similar in order for the flying disks to be classed as hallucinations.

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A large-scale experiment was made at the time of Orson Welles' "Martian" broadcast. Some records of this must exist in newspaper files.

Classification II -- Man-made terrestrial phenomena

1. The objects may be Russian aircraft. If this were so, then the considerations of Sections A and B indicate that we would have plenty to worry about. It is the author's opinion that only an accidental discovery of a degree of novelty never before achieved could suffice to explain such devices. It is doubtful whether a potential enemy would arouse our curiosity in so idle a fashion.

Classification III -- Extra terrestrial objects

1. Meteors: It is noteworthy that the British physicist Lovell writing in "Physics Today" mentions the polar discovery of a new daytime meteorite stream which reached its maximum during June 1947. The reported objects lose little of their interest, however, if they are of meteoritic origin.

2. Animals: Although the objects as described act more like animals than anything else, there are few reliable reports on extra-terrestrial animals.

3. Space Ships: The following considerations pertain:

a. If there is an extra terrestrial civilization which can make such objects as are reported then it is most probable that its development is far in advance of ours. This argument can be supported on probability arguments alone without recourse to astronomical hypotheses.

b. Such a civilization might observe that on Earth we now have atomic bombs and are fast developing rockets. In view of the past history of mankind, they should be alarmed. We should, therefore, expect at this time above all to behold such visitations.

Since the acts of mankind most easily observed from a distance are A-bomb explosions we should expect some relation to obtain between the time of A-bomb explosions, the time at which the space ships are seen, and the time required for such ships to arrive from and return to home-base.

PART III -- RECOMMENDATIONS

1. The file should be continued.

2. A meteorologist should now use the air estimate that y

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required to evaporate as much cloud as seen in the Incident 26 photographs. Together with an aerodynamicist he should examine whether a meteorite of unusual shape could have as observed.

3. The calculations suggested in Part II, Section A, should be activated by an aerodynamicist with such changes as his more detailed knowledge may suggest.

4. The mass-psychology studies outlined in Part II, Section C, Classification I 3 should be carried out by a competent staff of statisticians and mass-psychologists.

5. Interviewing agents should carry objects or moving pictures for comparison with reporter's memories. These devices should be properly designed by a psychologist experienced in problems pertaining to aircraft and design of aircraft-control equipment so that he shall have some grasp of what it is that is to be found out. If the Air Force has reason to be seriously interested in these reports, it should take immediate steps to interrogate the reporters more precisely.

6. A person skilled in the optics of the eye and of the atmosphere should investigate the particular point that several reports agree in describing the objects as being about ten times as wide as they are thick; the point being to see if there is a plurality of actual shapes which appear so, under conditions approaching limiting resolution or detectable contrast.

APPENDIX "B"

13 December 1948 AI-1009

Brigadier General Putt
United States Air Force
Director of Research and Development
Office, Deputy Chief of Staff, Materiel
Washington 25, D. C.

Dear General Putt:

Please refer to your letter of 18 November 1948 relative to the "flying object" problem and to Mr. Collbohm's reply dated 24 November 1948. In paragraph (b) of the reply, Mr. Collbohm promised (among other things) to send a discussion of the "special design and performance characteristics that are believed to distinguish space ships."

This present letter gives, in very general terms, a description of the likelihood of a visit from other worlds as an engineering problem and some points regarding the use of space vehicles as compared with descriptions of the flying objects. Mr. Collbohm will deliver copies to Colonel McCoy at Wright-Patterson Air Base during the RAND briefing there within the next few days.

A good beginning is to discuss some possible places of origin of visiting space ships. Astronomers are largely in agreement that only one member of the Solar system (besides Earth) can support higher forms of life. It is the planet Mars. Even Mars appears quite desolate and inhospitable so that a race would be more occupied with survival than we are on Earth. Reference 1 gives adequate descriptions of conditions on the various planets and satellites. A quotation from Ref. 1 (p. 229) can well be included here.

> "Whether intelligent beings exist to appreciate these splendors of the Martian landscape is pure speculation. If we have correctly reconstructed the history of Mars, there is little reason to believe that the life processes may not have followed a course similar to terrestrial evolution. With this assumption, three general possibilities emerge. Intelligent beings may have protected themselves against the excessively slow loss of atmosphere, oxygen and water, by constructing homes and cities with the physical conditions scientifically con-

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* It will be of this sort as visible. Perhaps underground RAND Corporation would be built or where the temperature extremes would be reduced.

trolled. As a second possibility, evolution may have developed a being who can withstand the rigors of the Martian climate. Or the race may have perished.

"These possibilities have been sufficiently explored in the pseudo-scientific literature to make further amplification superfluous. However, there may exist some interesting restrictions to the anatomy and physiology of a Martian. Rarity of the atmosphere, for example, may require a completely altered respiratory system for warm-blooded creatures. If the atmospheric pressure is much below the vapor pressure of water at the body temperature of the individual, the process of breathing with our type of lungs becomes impossible. On Mars the critical pressure for a body temperature of 98.6°F. occurs when a column of the atmosphere contains one sixth the mass of a similar column on the Earth. For a body temperature of 77°F. the critical mass ratio is reduced to about one twelfth, and at 60°F. to about one twenty-fourth. These critical values are of the same order as the values estimated for the Martian atmosphere. Accordingly the anatomy and physiology of a Martian may be radically different from ours - but this is all conjecture.

"We do not know the origin of life, even on the Earth. We are unable to observe any signs of intelligent life on Mars. The reader may form his own opinion. If he believes that the life force is universal and that intelligent beings may have once developed on Mars, he has only to imagine that they persisted for countless generations in a rare atmosphere which is nearly devoid of oxygen and water, and on a planet where the nights are much colder than our arctic winters. The existence of intelligent life on Mars is not impossible but it is completely unproven."

It is not too unreasonable to go a step further and consider Venus as a possible home for intelligent life. The atmosphere, to be sure, apparently consists mostly of carbon dioxide with deep clouds of formaldehyde droplets, and there seems to be little or no water. Yet living organisms might develop in chemical environments that are strange to us: the vegetable kingdom, for example, operates on a fundamentally different energy cycle from Man. Bodies might be constructed and operated with different chemicals and other physical principles than any of the creatures we know. One thing is evident: fishes, insects, and mammals all manufacture within their own bodies complex chemical compounds that do not exist as minerals. To this extent, life is self-sufficient and might well adapt itself to any environment within certain limits of temperature (and size of creature).

Venus has two features relative to Mars. Her mass, and gravity, are nearly as large as for the earth (Mars is smaller) and her

planet other than Earth would discourage astronomy, hence space travel. The remaining Solar planets are still poor prospects that they can be ignored.

In the next few paragraphs, we shall speak of Mars. It should be understood that most of the remarks apply equally well to Venus.

Various people have suggested that an advanced race may have been visiting Earth from Mars or Venus at intervals from decades to eons. Reports of objects in the sky seen to have been handled from through the generations. If this were true, a race of such knowledge and power would have established some form of direct contact. They could see that Earth's inhabitants would be helpless to do interplanetary harm. If afraid of carrying diseases home, they would at least try to communicate. It is hard to believe that any technically accomplished race would come here, flaunt its ability in mysterious ways and then simply go away. To this writer, long-time practice of space travel implies advanced engineering and science, weapons and ways of thinking. It is not plausible (as many fiction writers do) to mix space ships with broadswords. Furthermore, a race which had enough initiative to explore among the planets would hardly be too timid to follow through when the job was accomplished.

One other hypothesis needs to be discussed. It is that the Martians have kept a long-term routine watch on Earth and have been alarmed by the sight of our A-bomb shots as evidence that we are warlike and on the threshold of space travel. (Venus is eliminated here because her cloudy atmosphere would make such a survey impractical). The first flying objects were sighted in the spring of 1947, after a total 5 atomic bomb explosions, i.e., Alamogordo, Hiroshima, Nagasaki, Crossroads A and Crossroads B. Of these, the first two were in positions to be seen from Mars, the third was very doubtful (at the edge of Earth's disc in daylight) and the last two were on the wrong side of Earth. It is likely that Martian astronomers, with their thin atmosphere, could build telescopes big enough to see A-bomb explosions on Earth, even though we were 155 and 183 million miles away, respectively, on the Alamogordo and Hiroshima dates. The weakest point in the hypothesis is that a continual, intensive watch of Earth for long periods of time (perhaps thousands of years) would be dull sport, and no race that ever remotely resembled Man would undertake it. We haven't even considered the case for Venus or Mars, for example.

The sum and substance of this discussion is that if Martians are now visiting us without contact, it can be assumed that they'd've last recently succeeded in space travel and that their civilization would be practically abreast of ours.

The chance that another, under quite widely different conditions, would have a civilization resembling our own is extremely remote. It is particularly unlikely that their civilization would be within a half century of our own state of advancement. Yet in the last 50 years we have just started to use aircraft and in the next 50 years we will almost certainly start exploring space.

Thus it appears that space travel from another point within the Solar system is possible but very unlikely. Odds are at least a thousand-to-one against it.

This leaves the totality of planets of other stars in the Galaxy as possible sources. Many modern astronomers believe that planets are fairly normal and logical affairs in the life history of a star (rather than catastrophic oddities) so that many planets can be expected to exist in space.

To narrow the field a little, some loose specifications can be written for the star about which the home base planet would revolve. Let us say that the star should bear a family resemblance to the Sun, which is a member of the so-called "main-sequence" of stars, i.e., we eliminate white dwarfs, red giants and supergiants. For a description of these types, see reference 2, chapter 8. There is no specific reason for making this assumption except to simplify discussion: we are still considering the majority of stars.

Next, true variable stars can be eliminated, since conditions on a planet attached to a variable star would fluctuate too wildly to permit life. The number of stars deleted here is negligibly small. References 3, pages 78 and 88 indicate that the most common types are too bright to be in nearby space unnoticed. Lastly, we shall omit binary or multiple stars, since the conditions for stable planet orbits are obscure in such cases. About a third of the stars are eliminated by this restriction.

As our best known sample of space we can take a volume with the Sun at the center and a radius of 16 light years. A compilation of the 47 known stars, including the Sun, within this volume is given in reference 4, pages 52 to 57. Eliminating according to the above discussion: three are white dwarfs, eight binaries account for 16 stars and two triauries account for 6 more. The remainder, 23 stars, can be considered as eligible for habitable planets.

Assuming the above volume to be typical, the contents of any other reasonable volume can be found by varying the number of stars proportionately with the volume, or with the radius cubed, $S_e = 22 \times (\frac{r}{15})^3$, where S_e is number of eligible stars and r is the radius of the volume in light years. (This formula should only be used for radii greater than 15 light years. For smaller samples we call for a recount. For example, only one known eligible star other than the Sun lies within eight light years).

Having an estimate of the number of useable stars, it is now necessary to make a guess as to the number of habitable planets. We have only one observed sample, the Solar System, and the guess must be made with low confidence, since intelligent life may not be randomly distributed at all.

The Sun has nine planets, arranged in a fairly regular progression of orbits (see reference 1, Appendix I) that lends credence to theories that many stars have planets. Of the nine planets, (one, the Earth) is completely suitable for life. Two more (in adjacent orbits) are near misses: Mars has extremely rigorous living conditions and Venus has an unsuitable atmosphere. Viewed very broadly indeed, this could mean that each star would have a series of planets so spaced that one, or possibly two, would have correct temperatures, correct moisture content and atmosphere to support civilized life. Let us assume that there is, on the average, one habitable planet per eligible star.

There is no line of reasoning or evidence which can indicate whether life will actually develop on a planet where the conditions are suitable. Here again, the Earth may be unique rather than a random sample. This writer can only inject some personal intuition into the discussion with the view that life is not unique on Earth, or even the random result of a low probability, but is practically inevitable in the right conditions. This is to say, the number of inhabited planets is equal to those that are suitable!

One more item needs to be considered. Knowing nothing at all about other races, we must assume that Man is average as to technical advancement, environmental difficulties, etc. That is, one half of the other planets are behind us and have no space travel and the other half are ahead and have various levels of space travel. We can thus imagine that in our sample volume there are 11 races of beings who have begun space explorations. The formula on page 3 above now becomes

$$R = 11 \times (\frac{r}{15})^3$$

where R is the number of races exploring space in a spherical volume of radius $r \geq 15$ light years.

Arguments like those applied to Martians on page 3 need not apply to races from other star systems. Instead of being a "first port of call, Earth would possibly be reached only after many centuries of development and exploration with space ships, so that a visiting race would be expected to be far in advance of Man.

To summarize the discussion thus far: the chance of space travelers existing at planets attached to neighboring stars is very much greater than the chance of space-traveling Martians. The one can be viewed almost as a certainty (if the assumptions are accepted), whereas the other is very slight indeed.

In order to estimate the relative chances that visitors from Mars or star X could come to the Earth and act like "flying objects", some discussion of characteristics of space ships is necessary.

To handle the simple case first, a trip from Mars to Earth should be feasible using a rocket-powered vehicle. Once here, the rocket would probably use more fuel in slowing down for a landing than it did in initial takeoff, due to Earth's higher gravitational force.

A rough estimate of one-way performance can be found by adding the so-called "escape velocity" of Mars to that of the Earth plus the total energy change (kinetic and potential) used in changing from one planetary orbit to the other. These are 3.1, 7.0, and 10.7 miles per second, respectively, giving a total required performance of 20.8 miles per second for a one-way flight. Barring a suicide mission, the vehicle would have to land and replenish or else carry a 100% reserve for the trip home.

Let us assume the Martians have developed a nuclear, hydrogen-propelled vehicle (the most efficient basic arrangement that has been conceived here on Earth) which uses half its stages to get here and the remaining stages to return to Mars, thus completing a round trip without refueling, but slowing down enough in our atmosphere to be easily visible (i.e., practically making a landing). Since it is nuclear powered, gas temperatures will be limited to the maximum operating temperatures that materials can withstand (heat must transfer from the pile to the gas, so cooling can't be used in the pile). The highest melting point compound of uranium which we can find is uranium carbide. It has a melting point of 4560°R. Assume the Martians are capable of realizing a gas temperature of 4500°R (= 2500°K), and that they also have alloys which make high motor pressures (3000 psi) economical. Then the specific impulse will be I = 1035 seconds and the exhaust velocity will be c = 33,400 ft/sec (reference 5). Calculation shows that using a single stage for each leg of the journey would require a fuel/gross weight ratio of 0.96 (for each stage) too high to be practical. Using two stages each way (four altogether) brings the required fuel ratio down to .81, a value that can be realized.

If, by the development of strong alloys, the basic weight could be kept to 10% of the total weight for each stage, a residue of 9% could be used for payload. A four stage vehicle would then have a gross weight $\frac{(100)^4}{9}$ = 15,000 times as great as the payload: thus, if the payload were 2,000 pounds, the gross weight would be 30 million pounds at initial takeoff (Earth pounds).

Of course, if we allow the Martians to refuel, the vehicle could have only two stages* and the gross weight would be only $(\frac{10}{9})^2 = 123$ times the payload, i.e., 250,000 pounds. This would require bringing electrolytic and refrigerating equipment and sitting at the South Pole long enough to extract fuel for the journey home, since they have not asked us for supplies. Our dreams (electrolysis to make H_2) would be obvious to Martian telescopes and they might conceivably follow such a plan, particularly if they came here without foreknowledge that Earth has a civilization.

Requirements for a trip from a planet attached to some star other than the Sun can be calculated in a similar manner. Here the energy (or velocity) required has more parts: (a) escape from the planet (b) escape from the star (c) enough velocity to traverse a few light years of space in reasonable time (d) deceleration toward the Sun (e) deceleration toward the Earth. The nearest "eligible" star is an object called Wolf 359 (see reference 4, p 52), at a distance of 8.0 light years. It is small, having an absolute magnitude of 16.6 and is typical of "red dwarfs" which make up more than half of the eligible populations. By comparison with similar stars of known mass, this star is estimated to have a mass roughly 0.03 as great as the sun. Since the star has a low luminosity (being much cooler and smaller than the Sun) a habitable planet would need to be in a small orbit for warmth.

Of the changes of energy required as listed in the preceding paragraph, item (c), velocity to traverse intervening space, is so large as to make the others completely negligible. If the visitors were long lived and could "hibernate" for 80 years both coming and going, then 1/10 the speed of light would be required, i.e., the enormous velocity of 18,000 miles per second. This is completely beyond the reach of any predicted level of rocket propulsion.

If a race were far enough advanced to make really efficient use of nuclear energy, then a large part of the mass of the nuclear material might be converted into jet energy. We have no idea how to do this, in fact reference 6 indicates that the materials required to withstand the temperatures, etc., may be fundamentally unattainable. Let us start from a jet-propellant-to-gross-weight ratio of .75. If the total amount of expended material (nuclear plus propellent) can be .85 of the gross weight, then the nuclear material expended can be .10 of the gross. Using an efficiency of .5 for converting nuclear energy to jet energy and neglecting relativistic mass corrections, then a rocket velocity of half the velocity of light could be attained. This would mean a transit time of 16 years each way from the star Wolf 359, or longer times from other eligible stars. To try to go much faster would mean spending much energy on relativistic change in mass and therefore operating at lowered efficiency.

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* Actually three stages. On the trip to Earth, the first stage would be filled with fuel, the second stage would contain partial fuel, the third would be empty. The first stage would be thrown away during flight. On the trip back to Mars, the second and third stages would be filled with fuel. The gross weight of the initial vehicle would be of the order of magnitude of a two-stage rocket.

To summarize this section of the discussion, it can be said that a trip from Mars is a logical engineering advance over our own present technical status, but that a trip from another star system requires improvements of propulsion that we have not yet conceived.

Combining the efforts of all the science-fiction writers, we could conjure up a large number of hypothetical methods of transportation like gravity shields, space overdrives, teleports, simulators, energy beams and so on. Conceivably, among the myriads of stellar systems in the Galaxy, one or more races have discovered methods of travel that would be fantastic by our standards. Yet the larger the volume of space that must be included in order to strengthen this possibility, the lower will be the chance that the race involved would ever find the earth. The Galaxy has a diameter of roughly 100,000 light years and a total mass about two hundred billion times that of the Sun (reference 4). Other galaxies have been photographed and estimated in numbers of several hundred million (reference 2, p. 4) at distances up to billions of light years (reference 7, p 158). The number of stars in the known universe is enormous, yet so are the distances involved. A super-race (unless they occur frequently) would not be likely to stumble upon Planet III of Sol, a fifth-magnitude star in the rarefied outskirts of the Galaxy.

A description of the probable operating characteristics of space ships must be based on the assumption that they will be rockets, since this is the only form of propulsion that we know will function in outer space. Below are listed a few of the significant factors of rocketry in relation to the "flying objects".

(a) Maneuverability. A special-purpose rocket can be made as maneuverable as we like, with very high accelerations either along or normal to the flight path. However, a high-performance space ship will certainly be large and unwieldy and could hardly be designed to maneuver frivolously around in the Earth's atmosphere. The only economical maneuver would be to come down and go up more or less vertically.

(b) Fuel reserves. It is hard to see how a single rocket ship could carry enough extra fuel to make repeated descents into the Earth's atmosphere. The large number of flying objects reported in quick succession could only mean a large number of visiting craft.

Two possibilities thus are presented. First, a number of space ships could have come as a group. This would only be done if full-dress contact were to be established. Second, numerous small craft might descend from a mother ship which coasts around the Earth in a satellite orbit. But this could mean that the smaller craft would have to be rockets of satellite performance, and to contain them the mother ship would have to be truly enormous.

(c) Appearance. A vertically descending rocket might well appear as a luminous disk to a person directly below. Observers at a distance, however, would surely identify the rocket for what it really is. There would probably be more reports of oblique views than of end-on views. Of course, the shape need not be typical of our rockets; but the exhaust should be easy to see.

One or two additional general remarks may be relevant to space ships as "flying objects". The distribution of flying objects is peculiar, to say the least. As far as this writer knows, all incidents have occurred within the United States, whereas visiting spacemen could be expected to scatter their visits more or less uniformly over the globe. The small area covered indicates strongly that the flying objects are of Earthly origin, whether physical or psychological.

The lack of purpose apparent in the various episodes is also puzzling. Only one motive can be assigned: that the spacemen are "feeling out" our defenses without wanting to be belligerent. If so, they must have been satisfied long ago that we can't catch them. It seems fruitless for them to keep repeating the same experiment.

Conclusions:

Although visits from outer space are believed to be possible, they are believed to be very improbable. In particular, the actions attributed to the "flying objects" reported during 1947 and 1948 seem inconsistent with the requirements for space travel.

Very truly yours,

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JEL:sp

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