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Author: A. G. Haley

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developments leading to and the need for THE 1963 EXTRAORDINARY ADMINISTRATIVE RADIO CONFERENCE on space communications

by

ANDREW G. HALEY

At the outset, I must explain that I am deeply concerned over my failure in this paper to present a world-wide vista of the details of the plans and accomplishments of each nation in the field of astronautical radio. I necessarily have accumulated most of the " hardware " information contained herein from United States sources, I am familiar with, of course, and have used, in the preparation of this paper, such outstanding works as that of V. Petrov, of the USSR, who wrote " Television of the Future," which was published in Moscow, *Radio*, No. 6, June 1956, pp. 28-31, and also " Artificial Earth Satellites and the World Telecentre," published in *Zvezda*, No. 4, April 1957, pp. 160-164, and I have used many other outstanding papers by USSR scientists and engineers. I regret, however, that adequate translations from the Russian language of scores of splendid articles were not available. Likewise, I did not have the facilities nor the time to search the literature of the other great nations of the world. I must say that I was pleased indeed to obtain an abstract from a paper by Dr. J. Bůsák delivered at the First Czechoslovak Conference on Rocket Technique and Astronautics, organized by the Commission on Astronautics at the Czechoslovak Academy of Sciences at Liblice, near Prague, on April 22, and 23, 1960. Dr. Bůsák's paper was entitled, " Radio Communications and Cosmic Space Legal Problems," and the abstract read:

> " The regulations by international law of radio use in outer space could be based upon the work of the International Telecommunication Union (ITU), but requires very sound preparation. The Conference in Geneva in 1959 began regulation of the allocation of radio frequencies for outer space radio communications. The Conference recognized that existing regulations did not correspond to reality. Accordingly, in 1963, a special conference will be held to discuss this problem. The proposed conference should consider the studies made by ITU, the experience of countries which have launched space vehicles and the work of the permanent United Nations Committee on Outer Space. Financial and certain other problems will bring the discussion outside the competence of the ITU."

The story so far

Forty-three vehicles were launched into orbit or on space probe missions by the USSR and USA before there was a binding worldwide agreement on the use of the radio spectrum in astronautics. More than seventy-three radio transmitters were included in these space vehicles. Some of the transmitters are expected to continue operating indefinitely. *Vanguard I's* small 108.03 Mc/s transmitter, for example, is estimated to have an indefinite transmitter lifetime. It has been publicly announced that transmissions from these vehicles have been made on frequencies ranging from the region of 20 Mc/s to the region of 1000 Mc/s. It is understood that the range of frequencies used on a classified basis is even more extensive. And radio transmissions from earth to the space vehicles, both during and after launching, have involved large additional bands of the radio spectrum.

Despite representations made informally in 1952 and formally at Warsaw in 1956 it was not until December 21, 1959 (26 months after the launching of *Sputnik I*) that provision was made in the International Telecommunication Convention for radio allocations to the space and earth/space radio services. Prior to that time the astronautical services were not officially defined in the Convention, Radio Regulations or officially by any government. Radio frequencies were sometimes " cleared " on an informal basis for use in space programmes. On other occasions there was no attempt at " clearance." Thus, actual use of radio in astronautics antedated national and international agreement by more than two years.

The radio frequency allocations adopted at Geneva in 1959 are far from adequate for the present and future needs of existing, planned and foreseeable astronautics programmes. Many of the participants in the Geneva Conference recognized this fact. On the one hand the USSR and Czechoslovakian delegations at Geneva espoused the view that inadequate data existed to justify making civilian and world-wide allocations in the spectrum above 200 Mc/s. On the other hand the delegations of France, the United Kingdom and the USA urged that selected and definite frequencies throughout the spectrum from 2.5 Mc/s to 31 800 Mc/s be allocated to the space and earth/space radio services. Fortunately, before the end of the Conference there was one point of agreement—the several delegations unanimously decided that the frequencies allocated in 1959 would be inadequate for full scale astronautical telecommunications and service purposes.

An *ad hoc* Group representing the USSR, Czechoslovakia, France, the United Kingdom and the USA unanimously recommended, toward the end of the Geneva Conference, that an Extraordinary Conference be held in 1963 on four major matters related to astronautical radio allocations. The programme for the Extraordinary Conference recommended by the Group is:

(i) to examine the technical progress in the use of telecommunication for space research and the results of technical studies by the CCIR and other interested organizations (including, presumably, the IAF);

(ii) to decide on the allocation of frequency bands for the various categories of space telecommunication which are considered essential on the basis of the results of space research and technical studies;

(iii) to consider whether there is a continuing need for the allocation of some frequencies for space research purposes and if so to take appropriate action in this regard;

(iv) to adopt certain new provisions in the Radio Regulations to provide for the identification and control of radio emissions from space vehicles, taking into account the possible Recommendations of the CCIR, if such action is considered desirable.

In considering the forthcoming Conference the fundamental concern of scientists and engineers active in all aspects of cosmic communications and radio services, I am sure, is not solely related to the critical need for additional spectrum space. Overwhelming needs can be demonstrated without difficulty. In a more direct sense our task is to persuade Administrations that there is a need for the 1963 Extraordinary Conference during which undreamed shores and scientific vistas may be revealed to an enlightened forum. It is to the achievement of the latter salutary objective that this paper is in a meagre measure addressed.

THE 1959 ALLOCATIONS

The radio frequency allocations to the space and earth/space radio services adopted at Geneva are listed in Table I.

This table may be compared with prior proposals and requests for radio spectrum space which were made by the International Astronautical Federation, the American Rocket Society, the Committee on Space Research of the International Council of Scientific Unions and others. See for example, the IAF proposals, which I presented to the ITU at Geneva in August, 1959, as Official Observer of the IAF, which are listed in Table II.

It is apparent that the IAF requests were not fully met in the subsequent ITU allocations. The IAF fully documented the need for the allocations listed in Table II. Nevertheless, no allocations were made in the ranges 320-328.6 Mc/s, 890-942 Mc/s, 4380-4400 Mc/s, and 10 000-10 100 Mc/s, or in the spectrum reasonably near those bands.

CURRENT USE OF THE RADIO SPECTRUM IN ASTRONAUTICS

Approximately fifty space vehicles have been launched in the course of the satellite and lunar and space probe programmes of the USSR and the USA. Pertinent details as to frequencies, power and the like of the telecommunication equipment carried by these vehicles is shown in Table III.

The obvious fact must be borne in mind that this tabulation does not show the frequencies used in earth-to-vehicle transmissions. Also, the radio frequencies required for communications on earth incident to the original launching of the vehicles are not tabulated. An idea of the complexity of the telecommunication requirements for one vehicle is shown in Figure 1. Figure 1 describes the Ranger-Tonto moon vehicle complex which was recently scheduled by the National Aeronautics and Space Administration (NASA) for launching in 1961. A two-stage rocket vehicle (an *Atlas* and an *Agena-B*) will be used to propel a vehicle (Ranger) to the vicinity of the moon, where the capsule (Tonto) will be detached and landed on the moon with the assistance of a retrorocket. The Ranger will continue on to destruction upon impact with the moon.

In the overall Ranger-Tonto operation, practically every function of radio operation will be involved: communications and telemetering on the earth before and during launching; tracking, command, guidance, telemetry, and navigation during the journey; and telemetry after the landing on the moon. Television will be utilized for scanning the moon from the Ranger vehicle until its impact with the moon; radiotelegraph, radiotelephone and data transfer will be employed throughout the operation.

Table II. IAF Proposals to the ITU

Frequency band Mc/s	IAF Proposal Allocation to Services (World-Wide)
21.01	Astronautical Mobile (Ionospheric propagation)
37.00	Astronautical Mobile (Ionospheric propagation)
107.8-108.0	Astronautical Mobile Astronautical Radiolocation (Tracking)
148.0-150.8	Astronautical Radionavigation (Command)
320-328.6	Astronautical Mobile (Telemetry and Television)
450-455	Astronautical Mobile Astronautical Radiolocation (Tracking)
890-942 [1]	Astronautical Mobile
4380-4400	Astronautical Mobile
10 000-10 100	Astronautical Mobile Astronautical Radiolocation
17 500-20 000	Astronautical Mobile Astronautical Radiolocation
36 000-38 000	Astronautical Mobile Astronautical Radiolocation

[1] The frequency 915 Mc/s is designated for industrial, scientific and medical purposes. Emissions must be confined within the limits of ±25 Mc/s of that frequency. Radiocommunication services operating within those limits must accept any harmful interference that may be experienced from the operation of industrial, scientific and medical equipment.

Table I. Allocation of radio spectrum for space communication, Administrative Radio Conference, Geneva—December 1959

Frequency for space use	ITU regulation page	Status	Parent band	Primary use	Secondary use [9]	Region
10 003-10 005 kc/s	50	Footnote 215; and Rec. 31	9995-10 005 kc/s	Standard Frequency	Service for space research	Worldwide [1]
19 990-20 010 kc/s	53	Footnote 221; and Rec. 31	19 990-20 010 kc/s	Standard Frequency	Space and Earth-space services for research purposes	Worldwide [1]
39 986-40 002 Mc/s	56	Footnote 235	29.7-41 Mc/s	Fixed, mobile	Space [2], Earth-space [2]	Worldwide [6]
136-137 Mc/s	65	Allocation Table	136-137 Mc/s	Space [2], fixed, and mobile, Earth-space [2] [3]		Worldwide
183.1-184.1 Mc/s	70	Footnote 294	174-216 Mc/s	Fixed, mobile broadcasting	Space [2], Earth-space [2]	Worldwide [8]
400-401 Mc/s	72	Allocation Table	400-401 Mc/s	Meteorological aids, space, Earth-space [2]	RAS [4]	Worldwide [5]
1427-1429 Mc/s	80	Allocation Table	1427-1429 Mc/s	Space [2], fixed and mobile except aeronautical mobile, Earth-space [2]		Worldwide
1700-1710 Mc/s	82	Allocation Table	1700-1710 Mc/s	Fixed, region 1	Space [2], mobile, Earth-space [2]	Region 1 [6]
			1700-1710 Mc/s	Fixed, and mobile in regions 2 and 3	Space [2], Earth-space [2]	Region 2, 3
2290-2300 Mc/s	82	Allocation Table	2290-2300 Mc/s	Fixed, region 1	Space [2], mobile, Earth-space [2]	Region 1 [6]
			2290-2300 Mc/s	Fixed and mobile, regions 2 and 3	Space [2], Earth-space [2]	Regions 2, 3
5250-5255 Mc/s	89	Allocation Table	5250-5255 Mc/s	Radiolocation	Space [2], Earth-space [2]	Worldwide
8400-8500 Mc/s	91	Allocation Table	8400-8500 Mc/s	Fixed, and mobile	Space [2], Earth-space [2]	Worldwide [7]
15.15-15.25 Gc/s	95	Allocation Table	15.15-15.25 Gc/s	Space [2], Earth-space [2]	Fixed, and mobile	Worldwide [7]
31.5-31.8 Gc/s	97	Allocation Table	31.5-31.8 Gc/s	Space [2], Earth-space [2]	Fixed, and mobile	Worldwide

1. It is recommended that administrations take all practicable measures to safeguard the standard frequency bands from harmful interference.
2. For research purposes.
3. Aeronautical mobile (OR) service will be the primary service for as long as it continues to operate in this band. On discontinuation of this service, the space and earth-space services will be the primary services.
4. In the United Kingdom, the band 400-410 Mc/s is allocated to radiolocation service on a secondary basis.
5. In Greece, Yugoslavia, Albania, Bulgaria, Hungary, Poland, Rumania, Czechoslovakia, USSR, and Sweden, the band 400-401 Mc/s is also allocated to fixed and mobile services.
6. Bands are allocated on a secondary basis to the space and the earth-space services, subject to causing no harmful interference with the other services to which these bands are allocated.
7. In Australia and the United Kingdom, the band 8250-8500 Mc/s is allocated to the radiolocation service; the band 8400-8500 Mc/s is also allocated on a secondary basis, to the space and earth-space services for research purposes.
8. Allocation to space and earth-space services, for research purposes subject to causing no harmful interference.
9. Stations of a secondary service shall not cause harmful interference to stations of primary services and cannot claim protection from harmful interference of a primary service. They can claim protection from the same service (Radio Regulations No. 139, Geneva, 1959).

Table III. Space telecommunications data of US and USSR satellites, lunar and space probes (1957 to May 1960)
(Sputnik I through Pioneer V, official statistics prepared by NASA; the remaining, unofficial statistics)

Name	Lifetime	Transmitters	Power supply	Transmitter lifetime	Perigee (miles)	Apogee (miles)
Sputnik I	Oct. 4, 1957—Jan. 4, 1958	*(a)* 20 005 Mc/s; *(b)* 40 002 Mc/s	Chemical batteries	*(a)* and *(b)* stopped Oct. 27, 1957	142	588
Sputnik II	Nov. 3, 1957—Apr. 14, 1958	*(a)* 20 005 Mc/s; *(b)* 40 002 Mc/s	do	*(a)* and *(b)* stopped Nov. 10, 1957	140	1038
Vanguard test vehicle No. 3	Dec. 6, 1957	*(a)* 108 Mc/s at 10 mW; *(b)* 108.03 Mc/s at 5 mW	*(a)* Mercury battery; *(b)* 6 groups of solar converters	0	0	0
Explorer I	Jan. 31, 1958	*(a)* 108 Mc/s at 10 mW; *(b)* 108.03 Mc/s at 60 mW	Mercury batteries	*(a)* May 23, 1958; *(b)* Feb. 11, 1958, then Feb. 24-28, 1958	224	1573
Vanguard	Feb. 5, 1958, 57 sec.	Same as test vehicle No. 3			(1)	(1)
Explorer II	Mar. 5, 1958, 823 sec.	*(a)* 108.03 Mc/s at 60 mW; *(b)* 108.00 Mc/s at 10 mW	Mercury batteries		0	0
Vanguard I	Mar. 17, 1958, estimated 200-1000 y.	*(a)* 108 Mc/s at 10 mW; *(b)* 108.03 Mc/s at 5 mW	*(a)* Mercury batteries; *(b)* 6 groups of solar converters	*(a)* Apr. 5, 1958; *(b)* indefinitely	409	2453
Explorer III	Mar. 26, 1958—June 27, 1958	*(a)* 108 Mc/s at 10 mW; *(b)* 108.03 Mc/s at 60 mW	Mercury batteries	*(a)* May 10, 1958, then May 15—June 16; *(b)* May 14 then May 22—June 5	121	1746
Vanguard TV No. 5	Apr. 28, 1958	*(a)* 108 Mc/s at 80 mW	*(a)* Mercury batteries	?	(2)	(2)
Sputnik III	May 15, 1958	20.005 Mc/s and 40.01 Mc/s as first harmonic	Chemical and solar batteries	?	135	1167
Vanguard satellite launching vehicle No. 1	May 27, 1958, 20 min.	*(a)* 108 Mc/s at 80 mW	*(a)* Mercury batteries	20 min	(3)	(3)
Vanguard satellite launching vehicle No. 2	June 26, 1958	do	do	0	0	0
Explorer IV	July 26, 1958—Oct. 22, 1959	*(a)* 108 Mc/s at 10 mW; *(b)* 108.03 Mc/s at 24 mW	Mercury batteries	Sept. 3, 1958, then intermittent until Oct. 6, 1958	163	1380
U.S. lunar probe	Aug. 17, 1958, 77 sec.	*(a)* 108.6 Mc/s at 300 mW; *(b)* 108.09 Mc/s at 1 W	do		(4)	(4)
Explorer V	Aug. 24, 1958, 659 sec.	*(a)* 108.3 Mc/s at 30 mW; *(b)* 108.00 Mc/s at 10 mW	do	659 sec	0	0
Vanguard satellite launching vehicle No. 3	Sept. 26, 1958	*(a)* 108.00 Mc/s at 10 mW; *(b)* 108.03 Mc/s at 1 W	do	?	(5)	(5)
Pioneer I	Oct. 11, 1958—Oct. 12, 1958, 43 h. 17½ min	*(a)* 108.06 Mc/s at 300 mW; *(b)* 108.06 Mc/s at 1 W	do	Estimated 10 d	(6)	(6)
Beacon	Oct. 23, 1958	None			0	0
Pioneer II	Nov. 8, 1958, 42.4 min.	*(a)* 108.06 Mc/s at 300 mW; *(b)* 108.09 Mc/s at 100 mW	Mercury batteries	Estimated 10 d	(7)	(7)
Pioneer III	Dec. 6, 1958, 38 hours 6 min.	*(a)* 960.05 Mc/s at 180 mW	do	Estimated 90 h	(8)	(8)
Project Score	Dec. 18, 1958—Jan. 21, 1959	*(a)* 132.435 Mc/s; *(b)* 132.905 Mc/s minitrack; *(c)* 107.97 Mc/s; *(d)* 107.94 Mc/s	do	12 d (human voice transmission)	110	920
Lunik or Mechta	Jan. 2, 1959, in orbit around sun	*(a)* 19.997 and 19.995 Mc/s; *(b)* 19.993 and 183.6 Mc/s	?	?	(9)	(9)
Vanguard II	Feb. 17, 1959, est. 10 y.	*(a)* 108.00 Mc/s at 10 mW; *(b)* 108.03 Mc/s at 80 mW	Mercury batteries	*(a)* 23 d; *(b)* 27 d	347	2064
Discoverer I	Feb. 28, 1959—Mar. 5, 1959	Classified	Nickel-cadmium batteries	?	99	605
Pioneer IV	Mar. 3, 1959, in orbit around sun	960.05 Mc/s at 180 mW	Mercury batteries	90 h	(10)	(10)
Discoverer II	Apr. 13, 1959—Apr. 26, 1959	Classified	Nickel-cadmium batteries		142	220
Vanguard	Apr. 13, 1959, 500 sec.	*(a)* 108 Mc/s at 10 mW; *(b)* 108.03 Mc/s at 80 mW	Silver-zinc batteries	?	0	0
Discover III	June 3, 1959	Classified	Nickel-cadmium batteries		0	0

Table III *(continued)*

Name	Lifetime	Transmitters	Power supply	Transmitter lifetime	Apogee (miles)	Perigee (miles)
Vanguard satellite launching vehicle No. 6	June 22, 1959	*(a)* 108.0 Mc/s at 10 mW; *(b)* 108.03 Mc/s at 100 mW	Mercury batteries		0	0
Discoverer IV	June 25, 1959	Classified			0	0
Explorer	July 16, 1959	*(a)* 20 Mc/s at 650 mW; *(b)* 108 Mc/s at 15 mW	*(a)* Solar converters *(b)* Chemical batteries	*(a)* Cut off in 1 y; *(b)* 2 months	0	0
Explorer VI	Aug. 7, 1959, estimated 1 y.	*(a)* 108.06 Mc/s at 500 mW; *(b)* 108.09 Mc/s at 500 mW; *(c)* classified	Nickel-cadmium batteries rechargeable by 8000 solar cells on " paddlewheel " vanes	?	156	26 357
Discoverer V	Aug. 13, 1959—Sept. 16, 1959	Classified		?	136	450
Beacon	Aug. 14, 1959, 11.07 min.	108.03 Mc/s at 50 mW	Mercury batteries		0	0
Discoverer VI	Aug. 19, 1959—Oct. 20, 1959	Classified		?	139	537
Lunik II	Sept. 12, 1959, 6 *a.m.* e. d. t. impacted on Moon 5:02:24 *p.m.* e.d.t., Sept. 13, 1959	*(a)* 183.6 Mc/s in probe; *(b)* 39.986 Mc/s in probe; *(c)* 19.993 Mc/s in probe; *(d)* 20.003 Mc/s in rocket; *(e)* 19.997 Mc/s in rocket		35 h		236 875
Transit I	Sept. 17, 1959	*(a)* 54 Mc/s at 100 mW; *(b)* 162 Mc/s at 100 mW; *(c)* 216 Mc/s at 100 mW	2 silver zinc; 2 nickel-cadmium, rechargeable by solar cells	?	0	0
Vanguard III (satellite launching vehicle 7)	Sept. 18, 1959, estimated 30-40 y.	*(a)* 108.00 Mc/s at 30 mW; *(b)* 108.03 Mc/s at 80 mW	Chemical batteries	Programmed 35 h	319	2329
Lunik III	Oct. 4, 1959	*(a)* 183.6 Mc/s at 5-20 W; *(b)* 39.986	Chemical batteries and solar cells	?	24 840	292 000
Explorer VII	Oct. 13, 1959, estimated 20 y.	*(a)* 108 Mc/s at 10 mW; *(b)* 20 Mc/s at 600 mW; *(c)* 40 Mc/s at 15 mW; *(d)* 60 Mc/s at 5 mW	Solar cells and rechargeable nickel-cadmium batteries		342	680
Discoverer VII	Nov. 7, 1959	Classified			100	520
Discoverer VIII	Nov. 20, 1959	do			130	1035
Atlas-Able IV	Nov. 26, 1959	2—378 Mc/s at 5 W	Nickel-cadmium batteries, rechargeable by solar cells		0	0
Discoverer IX	Feb. 4, 1960	Classified			0	0
Discoverer X	Feb. 19, 1960	do			0	0
Midas	Feb. 26, 1960	do			0	0
Pioneer V	Mar. 11, 1960	2 at 378.21 Mc/s; *(a)* 5 W, which on command acts as amplifier for *(b)* at 150 W. (20 times more powerful than earlier space transmitters)	Nickel-cadmium batteries, rechargeable by 4800 solar cells	Indefinitely; on command. Successful reception from 1 000 000 miles on Mar. 18, 1960	(11)	(11)

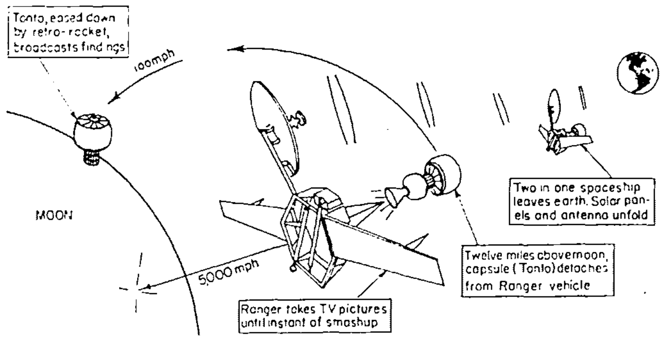
1. Altitude 20 000 feet.
2. Impacted 1500 miles from launching site.
3. Impacted 7500 miles from launching site.
4. Altitude 40 000-70 000 feet.
5. Estimated one complete orbit before impact.
6. Single trajectory—altitude 70 000 miles.
7. Altitude 963 miles.
8. Altitude 63 580 miles.
9. In orbit around sun on 15-month cycle.
10. In orbit around sun, tracked to 407 000 miles.
11. Planned to orbit around sun in 506 000 000-mile path.

Note. — Sputniks and Luniks are USSR, all the rest are US.

Addenda (Unofficial statistics)

Tiros	Apr. 1, 1960—21st Cent.	108.03 Mc/s, 107.997 Mc/s, and ?	Nickel-cadmium and solar cells	Indefinite	436	462
Transit I-B	Apr. 13, 1960—unknown	?	Nickel-cadmium and solar cells	Indefinite	177	436
Discoverer XI	Apr. 15, 1960—unknown; capsule down Apr. 26, 1960	?	?	?	103	573
Echo	May 13, 1960 launched, not successful	None, reflecting, sphere	None	None	—	—
Sputnik IV	May 15, 1960—unknown	19.995 Mc/s, 183.6 Mc/s	?	?	194	236

Fig. 1. Ranger Tonto Moon vehicle : telecommunications requirements



The telecommunications uses planned in connection with Ranger and Tonto and sketched in Figure 1 will be multiplied by a substantial factor when the first manned flight to the moon is made. A specific proposal for a 10 Mc/s band in the area 2290-2300 Mc/s will probably be made by the USA. This band would be used for television and other purposes in the " deep space areas," i.e., the moon and beyond. Describing this proposal and the basic problems affecting the selection and allocation of frequency space to astronautics projects, E. Rechtin of Jet Propulsion Laboratory states on behalf of Dr. W. H. Pickering and W. K. Victor:

" The preferred command frequency has not yet been selected. One of the most significant features of lunar and interplanetary communications is the use of directive antennas aboard stabilized spacecraft. Such antennas are required in order to obtain sufficient information from the moon and the planets to make the trip worthwhile. Under these conditions, deep space communications more nearly resemble a microwave relay link than any other conventional earth-communication system. Under these circumstances, the frequency choice tends to be in the region of 1000 to 10 000 Mc/s, the antennas tend to be of reasonable size (between 85' and 250' in diameter), and the radiated powers of 10 watts to 10 kilowatts aboard the vehicle are supplied by highly efficient and stable triodes and klystron amplifiers. The exception to this situation in deep space communications is the case of transmitting from the earth to an omnidirectional receiving antenna aboard the vehicle; in this situation, one tends to use very large ground antennas and consequently, somewhat lower frequencies. However, in this exception, the bandwidths are very narrow, the intention of the communication link is solely to direct the spacecraft to turn on equipment and to aim directive antennas at the earth and the use is infrequent.

" The principal difficulty with the present assignments is that there is insufficient bandwidth available between 2000 and 6000 Mc/s to accommodate the 24-hour communication satellites, lunar and interplanetary communications, precision ranging systems, and the like. This question quite possibly could be resolved by declaring that communication satellites would receive an allocation on strictly commercial grounds and that such communications are really not space communications for scientific purposes. The 24-hour communications satellite is a simpler way of building microwave links across continents and across oceans and has little or nothing to do with the exploration of space."

PROPOSED RADIO SPECTRUM REQUIREMENTS FOR ASTRONAUTICS

The nations of the world have made enormous investments in telecommunication equipment to support space programmes. Great Britain's Jodrell Bank radiotelescope is the largest in the world. It represents a major factor in the success of such programmes as the " Tiros ", and in tracking the space vehicles of all nations. The USSR has also made great expenditures for research and development in telecommunications related to the efficient use of the radio spectrum in space programmes. In the United States, major fiscal expenditures are planned for the space programme. For example, NASA's 1961 budget includes $32 550 000 for tracking, data acquisition, communications research, and the like. Within the NASA programmes there are five major technical objectives for 1961. They are:

(a) Improvement of the overall accuracy and efficiency of existing NASA tracking stations.

(b) Development of a prototype electronic tracking system of inherently greater precision than any present system.

(c) Development of communications techniques for spacecraft at planetary distances.

(d) Speedup of data handling to reduce timelag between the experiment and the conclusions.

(e) Development of special trajectory measuring techniques and systems for complex payloads.

The scientists of the world possess extensive knowledge as to the technical requirements for radio spectrum space in future astronautics programmes. Certainly by the spring of 1962 when the Extraordinary Conference will be scheduled (or could be postponed) our knowledge will be far more accurately and extensively developed.

The scope of requirements may be seen by an examination of public statements of representatives of government and industry in the United States. It is believed that the following information as to United States programmes is representative of the plans of the USSR, United Kingdom and other nations.

The US National Aeronautics and Space Administration's official estimates as to the numbers of major vehicle launchings in the next decade (commencing 1 July 1960) are listed in Table IV.

Some 260 major vehicles are thus planned for the next decade by the NASA organization alone. The total for all nations may be in excess of one thousand.

The scientists planning these and all other space programmes are faced with critical problems as to the adequacy of present radio allocations for the space and earth/space services. It is essential to inquire whether the telecommunication requirements of the 260 planned NASA vehicles as well as the 50 or more present space vehicles can be accommodated on the existing channels allocated to space and earth/space radio services. And can the space programmes of the USSR and other nations over the next decade be carried out using only the present radio allocations? These are fundamental questions which comprise the first major area of inquiry for the preparatory groups to answer before May of 1962.

Complex Factors

The complexity of the question is illustrated not only by the number of vehicles involved but by mission, length of transmission life, area of use, earth control of transmissions, and numerous other factors. A brief discussion of these factors follows.

The *Sputnik I* transmissions were useful for tracking and making pioneer experiments on radio propagation in space. While of essential importance the work of *Sputnik I* (and indeed of all succeeding space vehicles) must be increased in a truly geometrical ratio, and indeed beyond to a final elan worthy of mankind. In two and one half years the state of the art has progressed to a great degree: considerable information on geodesy, propagation, meteorology, the solar ultraviolet

Table IV. Anticipated major vehicle launching schedule by vehicle

Fiscal year	1960 *				1961				1962	1963	1964	1965	1966	1967	1968	1969
Redstone				1	2	3	2									
Atlas				1	2	1	2	1	6	1						
Juno I			1		1	3										
Thor-Able			2													
Atlas-Able				1	1											
Scout				4	2		2		6	6	6	6	6	6	6	6
Thor-Delta			1	1	1	2	1	1	5							
Thor-Agena B									1	6	6	6	6	6	6	6
Atlas-Agena B							1		3	4	5	6	3	12	12	12
Atlas-Centaur								1	5	4	5	6	9			
Saturn									2	2	3	4	4	4	4	4
Nova Type															1	2
Total	12				29				28	23	25	28	28	28	29	30

* Last two quarters only.

NASA mission target dates

Calendar year	
1960	First launching of a meteorological satellite First launching of a passive reflector communications satellite First launching of a Scout vehicle First launching of a Thor-Delta vehicle First launching of an Atlas-Agena-B vehicle (by the Department of Defence) First suborbital flight of an astronaut
1961	First launching of a lunar impact vehicle First launching of an Atlas-Centaur vehicle Attainment of manned space flight, Project Mercury
1962	First launching to the vicinity of Venus and/or Mars
1963	First launching of two stage Saturn vehicle
1963-1964	First launching of unmanned vehicle for controlled landing on the moon First launching Orbiting Astronomical and Radio Astronomy Observatory
1964	First launching of unmanned lunar circumnavigation and return to earth vehicle First reconnaissance of Mars and/or Venus by an unmanned vehicle
1965-1967	First launching in a programme leading to manned circumlunar flight and to permanent near-earth space station
Beyond 1970	Manned flight to the moon.

spectrum, X-rays in high atmosphere, auroral particles, radiation, system performance, and information concerning the composition of other bodies in our solar system have been transmitted to earth from the Russian and American vehicles. The USSR produced the first photographs of the reverse or " dark side " of the moon; the USA has determined the existence of the van Allen radiation belt; and we have learned of the transmission capabilities of small transmitters operating deep in space from *Pioneer V*. Telecommunications is the essential link by which data as to these matters were transmitted to earth.

With solar or nuclear energy power supplies the " life " of radio transmitters in space vehicles is practically unlimited. One of the *Vanguard I* transmitters may continue to operate for 200 to 1000 years, according to NASA. For many practical purposes, the future use of the frequency involved is restricted. The experience with this vehicle indicates a compelling need for international agreement on means to control and terminate transmission from space vehicles. Control is technically possible. We can command the various telemetering and other components of space vehicles in use at present. And by data storage means, information obtained at a given time can be recorded for transmission later on command from earth.

Fortunately, frequency sharing is possible in many aspects of space telecommunication. NASA has learned, for example, that frequency sharing is possible in many of its space programmes. Except as to high power scatter operations, area protection, rather than clear channel protection, is sometimes adequate. And where a transmitter in space can be controlled from earth, the transmissions of several vehicles can be " phased in " so as to operate at different times on the same channel.

R. K. Sherburne has informed me that equipment development for use in the frequency ranges 100-200 Mc/s is at a satisfactory stage; that a great variety of small and lightweight transmitters exist (for instance a usable two watt transmitter occupying fifty cubic inches is in existence). In the 1365-1660 Mc/s, and 2300-2500 Mc/s, areas, equipment is under development. In the 4400-4500 and 7125-8500 Mc/s regions, a full development programme is required.

Limitations and Parameters

The second major area of inquiry for the preparatory groups relates to the limitations and characteristic parameters of space radio systems to be operated in the foreseeable future. Such matters as the equipment characteristics, range, the nature of communications, interference and the like must be considered.

Wernher von Braun categorizes the limitations and required parameters of the major components of space vehicle telecommunication equipment as follows:

	Limitations	*Required parameters*
1. Antennas	physical size beamwidth	high gain small size
2. Power sources	capacity low efficiency large size	long life high efficiency small size
3. Transmitters	low power output low efficiency low operating frequency for high power output	high power high efficiency small size narrow bandwidths
4. Receivers	high noise factor poor sensitivity large size	high sensitivity low noise factor small size
5. Modulation subsystems	—	small size

The ranges of transmissions from space vehicles have been shown to be much greater than anticipated. Attenuation of radio signals from transmitters in space vehicles is of a lesser order than expected. *Pioneer V*, for example, travelled to a distance of 8 000 000 miles before the efficiency of its 5-watt transmitter became so low as to justify terminating its transmissions. The 5-watt transmitter had been scheduled to operate only to the extreme distance of 5 000 000 miles. Out to that range it was expected to transmit first 32 bits of information per second, then 16, 8 and finally 1 bit per second. The minimum transmission speed was not reached until the vehicle had reached almost the 8 000 000 mile mark.

Pioneer V's more powerful 150 watt transmitter is expected to produce signals receivable on earth at a distance of up to 50 000 000 miles. This is far in excess of what was estimated as its range prior to launching.

The attenuation of radio signals from space vehicles, the so-called " focusing effect " of the earth's atmosphere and other factors governing the effective range of transmitters must be determined with accuracy before the 1963 Radio Conference.

Recent achievements in the field of miniaturization have permitted scientists to concentrate a greater amount of specialized equipment into restricted limits of space and weight. The United States, for example, has been able to combine into one device three basic functions: telemetry, tracking, and command. The device is termed *Telebit*.

The designers of the Telebit system combined six major design objectives so that large amounts of information can be transmitted from space vehicles with only 10 pounds devoted to the transmission system in the vehicle. By increasing the weight of the system to 200 pounds, enough equipment could be carried so that a television picture could be transmitted from the moon. Naturally, the range of transmission and the size and weight of the transmitter will decrease the ability to send information. The relation of range to size and weight is shown in Figure 2.

Fig. 2. The Telebit system

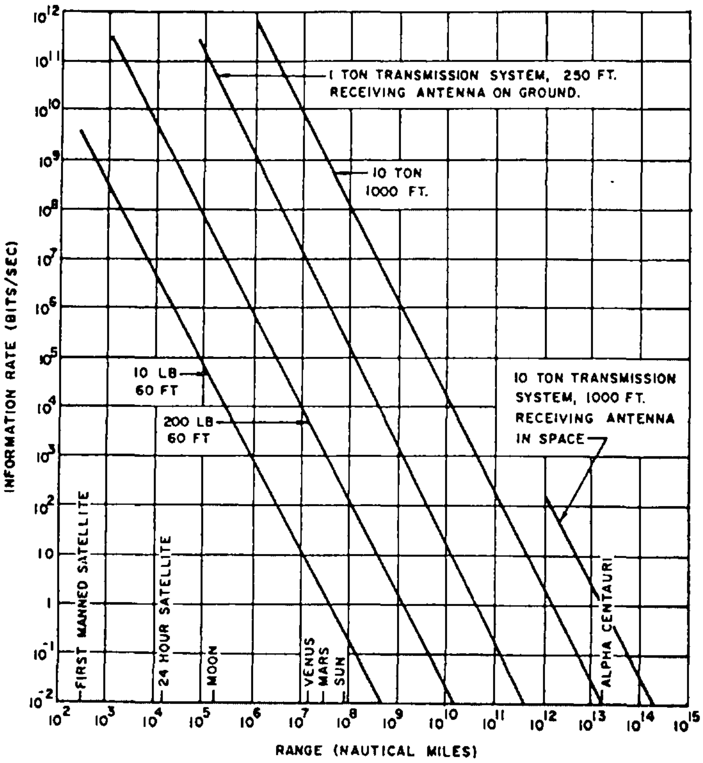


Fig. 2 was prepared by the Telebit system designers and represents present knowledge based on actual experience with the *Explorer* and *Pioneer* series of space vehicles.

It is not unreasonable to predict that our present day knowledge as to equipment characteristics and limitations will be vastly improved and expanded well before the time of the 1963 Conference.

Data on Scientific Phenomena

The preparatory groups must also develop for the International Telecommunication Union data as to scientific phenomena affecting the foreseeable uses of radio in astronautics. One critical phenomenon is the " plasma effect," described by Darrell Romick and The Goodyear Astronautics Department:

> " Highest attenuation rates, caused by hypersonically generated plasma surrounding re-entering vehicles, occur over the 10 Mc/s to 10 Gc/s region. It appears that transmission may be effected by utilizing the VLF, microwave, or even the optical band. However, due to the disadvantages inherent with very low or extremely high frequencies, methods of communicating through the plasma over the VHF-UHF bands are being examined."

It is known that in transmissions among Earth, satellites, Moon, Venus, Mars, and other planets other phenomena must be considered. The Doppler shift at all positions (on Earth, on the vehicle, on the Moon and planets) must be considered. The Doppler effect in space flight is illustrated in Figure 3.

The axial rotation of the planets, Faraday rotation, and tracking and stabilization of the same are other factors for study and consideration.

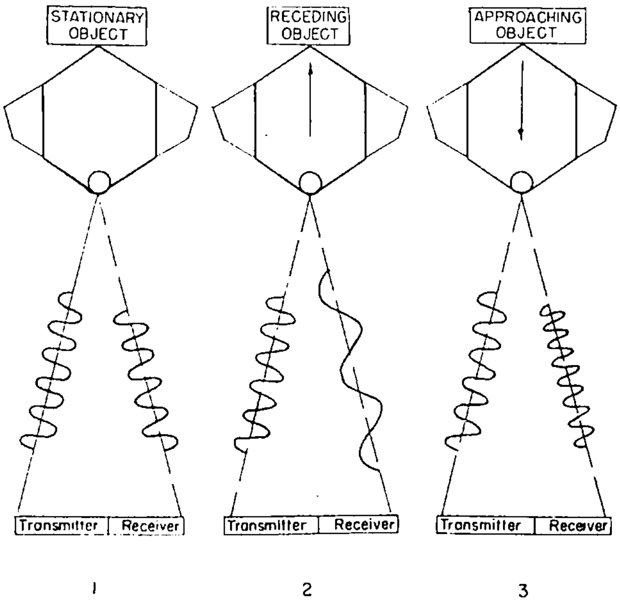


Fig. 3. The Doppler shift in space telecommunication

Extraterrestrial noise – galactic noise, radio stars, solar radiation, planetary radiation, and other factors—affect the selection of frequencies. Noise within the equipment is a factor affecting both receiver and transmitter performance.

S. F. Singer comments as follows on the effects of extraterrestrial phenomena on frequency selection:

" With our increasing knowledge concerning the nature of atmospheres, and with our better knowledge of the emission of radiation from the Sun, which produces an ionosphere, one can now start to make certain predictions concerning the likely electron density of these planets. Furthermore, one can derive thereby the radio frequencies which can be transmitted through such a planetary atmosphere to establish, for example, communication with a station on the surface of the planet. It is well known that in the case of the earth, the earth's ionosphere limits communication to frequencies above 15 Mc/s, preferably higher. It would be important to establish even now the likely range frequencies which can be transmitted through the gaseous envelopes of other planets which are likely to be the target of space exploration during this decade."

Various Types of Emission

The preparatory groups must assemble data as to the comparative efficiency of the several types of emission proposed for telecommunication in space. There have been described in technical journals various types of emission—AM, FM, FM/FM, PCM, and others. The exact operating parameters of vehicle, antenna, power supply and nature of intelligence will all enter into the determination of the emission requirements. J. R. Dempsey of Convair Astronautics has furnished considerable data as to these factors. He advises,

" In general, multiple modulation systems such as FM/FM result in loss of power efficiency but make possible multiple data channels on a single carrier. It can be shown under certain signal-to-noise ratios that AM or single sideband AM is more efficient than FM for voice communications. Under strong signal conditions the converse can be shown to be true. Digital transmission methods will ' nd much use in future space communications system . Thus, we do not find it desirable to limit the transmission to a particular type of transmission on a general basis but rather to define the frequency spectrum to be made available."

Special Projects

Finally, the needs of special projects such as satellite-borne weather observation instruments, communications relays, interplanetary navigation, and a new system of terrestrial navigation using radio signals from earth satellites, must be studied by preparatory groups.

The use of space vehicles in weather observation has reached a meaningful stage of development. We could today supply the CCIR with extensive data as to the radio spectrum requirements of such programmes. Photographs of cloud cover and other meteorological data have been gathered by *Tiros I*, developed by NASA, the US Army and Radio Corporation of America. The satellite comprises one of the most elaborate electronics packages yet sent into orbit around the earth. It includes miniature television cameras, video tape recorders, transmitters, solar cell and rechargeable battery power supplies, and an array of control and communications equipment. In the first four days of its operation, *Tiros* sent by television nearly 1200 pictures. The 2-watt transmitters operate in the 200 Mc/s region of the spectrum. The tape recording facilities include 400 ft. of specially developed tape which can be used repeatedly.

Similarly, substantial data are now available as to space communications relays. J. R. Pierce's original work on " Orbital Radio Relays " contained one of the first scientific approaches to the matter of space communications satellites. Pierce foresaw situations where up to 10 megawatts power would be required for the transmission to a 1000 ft. sphere of a 5 Mc/s video signal. He calculated that greater power would be required for smaller spheres, and drastically reduced power for a system utilizing several satellite repeaters.

The original Pierce work was viewed with some scepticism, but we are now aware that actual satellite relays are within the realm of reality. At least one of the industrial giants of the United States has joined in a programme of actual operation, albeit an experimental one: NASA in conjunction with Bell Telephone Laboratories has initiated Project Echo. This is the most ambitious passive communications satellite project yet undertaken. The gigantic sphere used for relay will be launched into orbit inflated in space, and operated on an experimental basis. The frequencies 960 Mc/s and 2390 Mc/s will be utilized in this project. It is estimated that a successful relay system could carry 900 voice messages simultaneously, whereas the present Atlantic cables can handle less than 160 calls simultaneously.

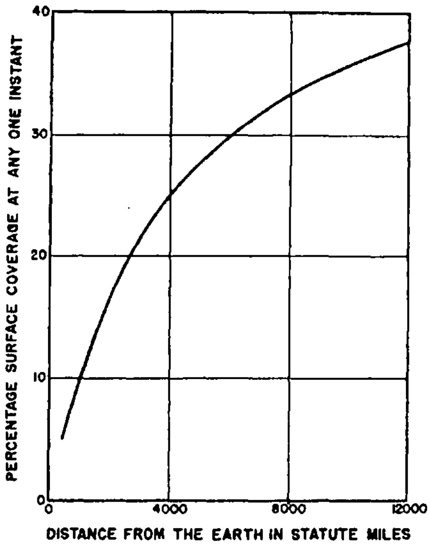
Radio Corporation of America, which is also involved in transoceanic common carrier communications, has also developed keen interest in space relays. RCA is known to have underway extensive research into space relay systems, and an extremely wide frequency band width for such communications has been mentioned informally.

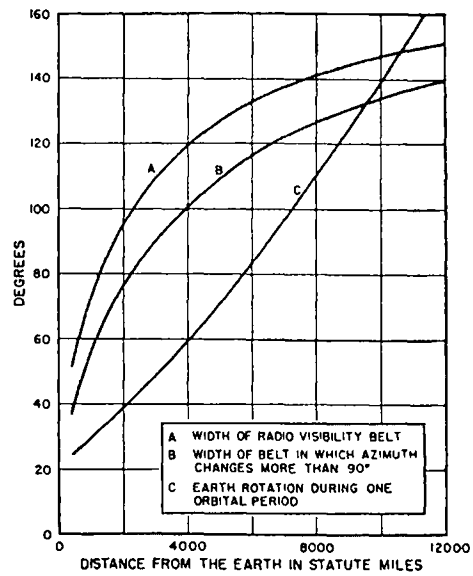
Navigation Systems

Navigation systems utilizing radio transmissions in space form a large part of present research and development in the fields of astronautical sciences. In many respects, position fixing in space involves techniques similar to those used on earth. Nevertheless, substantial differences exist in the two fields, and telecommunications affords the essential servant to assist in the determination of positions in space. J. R. Dempsey has advised me that a system for determining positions in space is in an advanced stage of development. He states,

" One of the most promising techniques involving high precision radio navigation was described in a paper presented by J. W. Crooks, Jr. of Convair-Astronautics at the 1959 Ballistic Missile Symposium in Los Angeles, California. This system involved communication at microwave frequencies between two or three ground stations and a space craft at ranges up to the distance of Saturn. Since this system provided high precision it was proposed that perturbation of the space vehicle orbit as it approached the target planet be used for determining the relative location of the vehicle and the planet for purposes of terminal guidance.

" The navigational system described above would involve frequencies in the microwave region, optimum probably being between 1000 and 10 000 Mc/s. The frequency transmitted from the ground transmitter and the frequency retransmitted from the space vehicle would be approximately related by a common multiple. For example, the frequency transmitted on the ground might be approximately 5050 Mc/s and the frequency returned by the space craft be 5000 Mc/s, where one is the 100th harmonic of 50 Mc/s and the other is the 101st harmonic. In addition, these signals would be modulated with sub-carriers possibly ranging as high as one megacycle. Data bandwidths involved in this system would be extremely narrow, much less than a cycle per second, even though the sidebands may extend out beyond a megacycle of either side of the carrier. This type of operation is typical for CW range systems employing correlation detection techniques. The emission would have the general characteristics of narrowband frequency modulation systems with discrete modulation frequencies up to one megacycle or higher. Frequency allocations should allow for doppler shifts."





An earth navigation system using reflected transmissions from natural or artificial objects has been proposed, and research into this project is underway. One proposal is to place three or four satellites in orbits at distances of from 1000 to 12 000 miles from earth. Signals from such satellites would be utilized in determining position on earth.

The proponent of this theory, Alton B. Moody, recognizes the possibility of error, and the inability to obtain total coverage of the earth at any time, and he has portrayed the problem as visualized in Fig. 4.

The extent of the radiofre quency requirements for such a system must be a matter of concern to those preparing recommendations for the 1963 Conference.

AGENCIES AVAILABLE FOR PREPARATORY WORK

The International Radio Consultative Committee (CCIR) of the ITU is the body called upon " to study technical radio questions and operating questions the solution of which depends primarily on considerations of a technical radio character and to issue recommendations on them ". Its Study Group IV (Space Systems) has been formed " to study systems of telecommunications with and between locations in space."

In the United States, a Working Group headed by Dr. John P. Hagen, of the National Aeronautics and Space Administration, has commenced its work of assembling basic data for the potential 1963 Conference.

The American Rocket Society has established Committees on Space Communications and Guidance and Navigation, and the constituent societies of the IAF have contributed greatly to theoretical and practical research in the field of astronautical radio.

The International Astronautical Federation has received official status as an Observer in the work of the ITU, and has the right to participate in Administrative Conferences of the Union and in the meetings of the CCIR.

Thus, there are numerous existing scientific and technical bodies fully equipped to assemble data for the 1963 Conference.

THE PROGRAMME

The programme outlined below is presented as a first approximation of what should be done to prepare for the 1963 Conference. The scientists, engineers and administrators who will actually place the programme into operation will unquestionably revise and extend it. But the work must be undertaken now, and it must be completed to a substantial extent prior to May of 1962. By that time a comprehensive report must be delivered to the Administrative Council of the ITU. The report must contain proof of the existence of sufficient data to justify the convening of the 1963 Conference.

The representatives of several United States government agencies, industrial groups and scientific and educational organizations have been consulted as to a preparatory programme for the 1963 Extraordinary Administrative Radio Conference. They have donated their time and effort on an individual basis to the review and criticism of the programme. Their participation has been entirely unofficial and in no way represents viewpoints based on their official or professional associations.

As the task is a worldwide one requiring international co-operation, I am urging that the International Astronautical Federation serve as a central fact-finding body, and that a special committee be established within the IAF for the preparation of recommendations to the CCIR.

The constituent societies of the IAF will undoubtedly co-operate with their national administrations in the preparation of basic data for the 1963 Conference. The American Rocket Society, for example, is preparing technical data in response to a formal Notice of Inquiry issued by the Federal Communications Commission (FCC) on May 19, 1960, " as to frequency needs for space communications on a longer-range basis, in view of the expected rapid developments in space communications ". The FCC has stated that " This technical information will assists the Commission in its preparatory work leading to a United States position for future international conferences on space communications needs." The information sought by the FCC must be supplied no later than March 1, 1961. The FCC concurrently reopened its overall inquiry into allocations in the microwave range (above 890 Mc/s) to receive factual data as to frequency needs for space communication.

Compilation of data for the use of national administrations should be conducted simultaneously with the preparation of technical reports for formulation of the IAF's position on space telecommunication needs.

The programme which I offer as the starting point for the IAF committee is set forth below:

A. Limitations and characteristics of space radio uses

1. What frequencies, general types of modulation, band widths, power level and other operational factors have been involved in space programmes of the USA and USSR to date?
   - *(a)* Vehicle type
   - *(b)* Spacecraft

2. What is the present extent of knowledge as to the following factors affecting frequency selection?
   - *(a)* Space and weight limitations on transmitting equipment in the vehicle
   - *(b)* Power source limitations
   - *(c)* Antenna arrays
     - *(i)* Space based
     - *(ii)* Earth based
   - *(d)* Area in which used
     - *(i)* transmissions through the earth's atmosphere and ionosphere, especially attenuation of radio transmissions from space vehicles
     - *(ii)* transmissions not passing through the earth's atmosphere and ionosphere
   - *(e)* Time phasing and frequency sharing: periods when various portions of the spectrum will be used
   - *(f)* Cosmic and solar noise background
   - *(g)* Data bandwidth
   - *(h)* Receiver noise figure limitations

3. What are the limitations and the characteristic parameters required for space radio systems in the foreseeable future?
   - *(a)* Frequencies
   - *(b)* Nature of communications
     - *(i)* Telephone
     - *(ii)* Telegraph
     - *(a)* Facsimile
     - *(b)* Photo transmissions
     - *(iii)* Television
     - *(iv)* Data transfer
     - *(v)* Other
   - *(c)* Interference
   - *(d)* Ranges
   - *(e)* Costs
   - *(f)* Efficiency
   - *(g)* Effects of atmosphere and ionosphere
   - *(h)* Equipment characteristics
     - *(i)* Antennas—physical size and beamwidth
     - *(ii)* Power sources—capacity, efficiency, size
     - *(iii)* Transmitters—power output, efficiency, frequency, bandwidth
     - *(iv)* Receivers—sensitivity, noise factor, size
     - *(v)* Modulation subsystems
     - *(vi)* Others
   - *(i)* Ground receiving and transmitting equipment
   - *(j)* Classes of satellites proposed for relay communications
     - *(i)* Low attitude passive
     - *(ii)* Low attitude active
     - *(iii)* 24 hour orbit passive
     - *(iv)* 24 hour orbit active
     - *(v)* planets, artificial minor planets, etc. as satellites
   - *(k)* Sensitivity

B. Foreseeable uses of radio in astronautics and frequencies required therefor

4. What are the nature and extent of the problems of radio transmission from Earth to positions in space such as Mars, Venus and Moon? And from Earth to a satellite, and thereafter to a position in space such as Mars, Venus and Moon?
   - *(a)* Doppler shifts due to the relative motion of the earth and of the planets
   - *(b)* Faraday rotation, tropospheric and ionospheric absorptions, bending and diffusion
   - *(c)* Tracking and stabilization of antennas on planets
   - *(d)* Axial rotation of planets
   - *(e)* Communications systems on planets—effects of lack of ionosphere around planets on beyond line of sight transmissions
   - *(f)* Others

5. To what extent is extraterrestrial noise a factor in space communications?
   - *(a)* Galactic noise
   - *(b)* Radio stars
   - *(c)* Solar radiation
     - *(i)* constant
     - *(ii)* sudden ionospheric disturbances (I.D.)
   - *(d)* Planetary radiation
   - *(e)* Other factors

6. With particular reference to interplanetary telemetering by means of telecommunications, what is the extent of present knowledge and what are the foreseeable requirements of
   - *(a)* Equipment
     - *(i)* frequency requirements
     - *(ii)* power supply
     - *(iii)* antenna characteristics
     - *(iv)* type of modulation
   - *(b)* Uses of telemetry

7. With reference to the allocations for space radio purposes adopted at the 1959 Radio Conference in Geneva, what additional spectrum space should be proposed for space radio uses in the following bands?
   - *(a)* Research
   - *(b)* Commercial and military
   - *(c)* Sharing 2500 kc/s to 25 Mc/s
25 Mc/s to 8700 Mc/s
890 Mc/s to 8700 Mc/s
8700 Mc/s to 35 000 Mc/s
above 35 000 Mc/s

8. What are the foreseeable frequency allocation requirements of the several uses of radio in astronautics?

- *(a)* Tracking
- *(b)* Command
- *(c)* Guidance
- *(d)* Telemetry
- *(e)* Communications
- *(f)* Navigation
- *(g)* Research
- *(h)* Reentry; the plasma effect; achievement of control on occasion of reentry
- *(i)* Others

9. What bandwidths will be required for the foreseeable future?

10. What provisions should be made for identification and silencing?

11. What provisions should be made for guard bands?

12. Information rates.

C. Comparative efficiency of the several types of emission proposed for communications in space

13. Utilizing a single basis of comparison what are the relative efficiencies of the several communications systems available for transmissions from space vehicles;

- *(a)* AM
- *(b)* FM
- *(c)* FM/FM
- *(d)* Orthogonal matched filter communications system
- *(e)* PCM (pulse code modulation)
- *(f)* Other systems
  - *(i)* Time multiplying pulse code
  - *(ii)* Pulse duration modulation

D. Interplanetary navigation

14. In what manner and to what extent could a system using natural electromagnetic radiation in the space environment be used for navigational purposes?

15. In what manner and to what extent could a system using Doppler radar and ranging or some similar form of electromagnetic radiation be used for navigational purposes in the space environment?

16. What frequencies, bandwidth and emission will be required for the operation of a navigation system such as that described in paragraphs 14 and 15 above?

E. Navigation on Earth using signals from high altitude satellites

17. Can celestial navigation and electronics be combined to produce a system having the universality of a celestial system and the all-weather capability of electronics, with essential freedom from the limitations encountered by present systems?

18. What would be the equipment requirements?

- *(a)* Antenna size and characteristics
- *(b)* What frequencies would be most suitable
- *(c)* What power sources would be needed

19. What method of determining distance would be used?

- *(a)* Measurement of the Doppler shift
- *(b)* Angle measurement

20. How many satellites would be required for navigation system?

21. What degree of accuracy could be achieved?

22. What installations on earth would be required?

23. What will be the frequency requirements?

F. What other major categories of data should be developed in connection with the study of the adequacy of present provisions for space radio needs?

24. What provisions should be made for Search and Rescue?

- *(a)* Transmission region
  - *(i)* Satellite to earth search
  - *(ii)* Earth to satellite search
  - *(iii)* Satellite to satellite search
  - *(iv)* Distress frequency for use in space
- *(b)* Use of normal " distress frequency "—protection and allocation of a higher frequency
- *(c)* Use of interrogation frequency (command) normal and higher frequencies
- *(d)* Use of rebroadcast frequency

25. What provisions should be made for mission problems and requirements?

26. What are the particular problems affecting the use of the radio spectrum in space regions only, e.g., Mars to Venus, or from deep space probe to a communication satellite, and what provisions therefor should be made in the International Telecommunication Convention?

- *(a)* Use of low frequencies for non-earth reception
- *(b)* Allocation of frequencies for guidance and navigation (Loran, etc.)
- *(c)* Planetary atmospheres and ionospheres.