TECHNICAL ASPECTS OF RUSSIA AND THE USA COOPERATION IN THE AREA OF DEEP-SPACE TRACKING NETWORKS. EXPERIMENTAL RESULTS.

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There are two global deep-space tracking networks operating now in the world: in Russia and in the USA.

Principally one can find no fundamental differences in tasks to be solved by the facilities of russian and american networks which control the deep-space vehicles, but there are certain differences in the technology of fulfilling the operations on the spacecraft control.

These differencies are caused mainly by the logical peculiarities in the organisation of work of russian and american spacecrafts, as well as by the fact, that the organisation structures for providing the s/c control in Russia and in the USA, have gone their own alternative development ways. The solving of problems connected with the spacecraft control requires the conformity of variety of major technical parameters of ground and on-board radiotechnical facilities.

Among these parameters are:

- operating frequency bands;
- modulation types in the radiolinks;
- signal structure in the command radiolink;
- signal structure in the TM radiolink;
- types of interference-suppressing codes in radiolinks and a number of other parameters.

Nowadays the russian DSCN and the american DSN have got distinctions practically in all mentioned technical parameters.

In order to achieve the international cooperation when dealing with deep-space vehicles it is necessary to assure the compatibility of both ground tracking networks in all technical characteristics. Besides of this it is necessary to perform a number of undertakings of organisational manner, that is:

- to establish additional structures which will provide the interoperability of systems;
- to arrange communication channels between russian and american networks for exchanging the technological data and the data to be sent to spacecrafts and received from them.

The USA and Russia cooperation in the sphere of deep-space investigations can be progressed in three directions:

- participation of the russian DSCN in supporting the american space programs;
- supporting of russian space missions by the USA facilities;
- integration of russian and american facilities with the aim to establish the associated international ground control center (complex).

Potentialities of russian DSCN to support american space missions.

It seems that the american side is interested in usage of russian network capability to support a number of american missions, mainly the spacecrafts with the earliest terms of launching, such spacecrafts as Voyager, Cassini , Mars and so on.

It is obvious that primarily the russian 70-m reflector antennas will be demanded, which allow to carry out the following operations:

- reception of TM data (scientific and housekeeping);
- trajectory measurements fo american spacecrafts in the non-interrogation mode (triple doppler);
- participation in the interferometric measurements;
- summation of signals from several antennas.

In order to make the russian and american networks compatible it would be necessary to perform essential upgrading of russian network hardware, that is:

- to introduce the new operating frequency bands X and S, for this aim the antennas must be modified, new receiving arrangements must be developed and fabricated;
- to develop receivers, demodulators, decoders and TM data recorders in accordance with the american structure including the design and reqimes recommended by the CCSDS;
- to develop the trajectory measuring equipment compatible with the american equipment and so on.

At later stages it could be demanded to provide the compatibility of command radio links and to develop for this purpose the new radio transmitters and command radio equipment.

The signal structure of american spacecrafts is not unified. The CCSDS recommendation on the signal structure are expected to be fulfilled only for the spacecrafts which are under development now and will be launched in nearest years. Therefore, the creation of an united system of TM data reception from all spacecrafts is douptful. Probably it would be necessary to develop several kinds of devices for the data demodulation, decoding and recording with taking into account the peculiarities of signals acquired different spacecrafts and to assemble a system for the TM data from reception from these devices.

The development of these devices must be carried out step-be step in dependence on the decision that this or that mission will be served by the russian tracking network.

One of the modes for performing the trajectory measurements by american tracking stations is the mode of ’’triple doppler’’, when one of stations radiates an interrogative signal and several others (2-3) receive this signal, relayed from the satellite, and make measurements of the doppler frequency in the non-interrogative mode.

The special equipment intended for long sessions of doppler measurements in the background of TM data reception must be developed.

The gathered data are recorded during the session to the magnetic disc of the PC with large memory capacity and then rewritten into diskettes which must be sent to the USA.

Principally the TM data could be delivered to the USA in real or quasi-real time (with reduction) through the specially arranged channels of data transmission.

It is impossible to overevaluate the importance of joint operations of russian tracking stations in combination with american and european VLBI networks when great experience was gained during execution of russian space mission Vega and later, when the russian tracking stations equipped with systems Mark-II, VLBA and S2 were involved for the VLBI measurements.

Potentialities of american tracking network to support russian space missions.

Currently there is an agreement signed on participation of american institutions in implementing of russian missions “Mars-96” and “Radioastron”.

On the program “Mars-96” it is envisaged that the DSN will be used for the navigational interferometric measurements of the spacecraft M96. For this purpose a special low-power transmitter of X-band will be installed on the spacecraft.

On the Radioastron program it is expected that the radioastronomical observations will be carred-out and the tracking stations of the USA, Canada, Japan, Australia, Germany will be involved.

Potentialities of integration of american and russian deep-space tracking networks.

The russian DSCN and american DSN are engaged into solving of identical tasks, but they use different techniques for the control implementation. This fact can be explained by peculiarities in the pholosophy of organising the work of spacecrafts in Russia and in the USA as well as by differencies in organisation structures which provide the control of spacecrafts.

Three conditions should be noted the fulfillment of which would allow to integrate the russian and american tracking networks:

1) Compatibility of the tracking stations hardware must be assured.

2) Organisational structures providing the interoperability of control systems must be created.

3) Communication channels between russian and american networks for the data exchange during control must be arranged.

Probably, the integrated tracking network will prove itself as the most reasonable when implementing the joint russian-american missions of the deep-space investigation, such as Mars Together, Pluton, Radio Science, Planetary Radar, Space Geodesy and so on.

Experimental results of the work of russian DSCN with american spacecraft “Voyager”.

With the purpose to determine the practical capabilities of the russian DSCN to support american space missions the joint decision was adopted to carry out a number of experimental sessions for reception of TM data and a series of doppler measurements from american spacecrafts “Voyager” by the russian tracking station in Ussuriisk, equipped with 70-m antenna.

The main differences between signals of the spacecratf Voyager and signals of russian tracking station are shown in Table 1.

Table 1.

Main differences between signals of the s/c Voyager and russian DSCN.

N	Signal parameters	s/c Voyager	Russian DSCN
1	Frequency band for received signals.	X	L, C
2	Number of the signal modulation steps.	3	2
3	Nominal value of the signal subcarrier frequency.	22.5 kHz	-
4	TM data capacity.	160.600 baud	512 baud - 65,536 kbaud, with the step being a multiple of the exponent of the two
5	Coding technique.	Convolution code	Convolution code with

		with K=7, R=1/2	K=6, R=1/2

The equipment of the russian tracking station was finished with the aim to reach the full compatibility with the signal of american s/c Voyager.

For performing these works the efforts have been made on developing and putting into operation at the tracking station the antenna feed and low-noise receiver of the X-band, the decoder of convolution code with K=7, the simulator as well as needed software for the digital receiver and for the PC which accomplishes the data processing and recording. The data recorded on flexible discs were sent to the JPL for processing.

During implementing the sessions of the TM data reception the programs developed for the digital receiver-demodulator were used for:

- tracking the carrier frequency of the signal;
- tracking the signal of subcarrier frequency 22.5 kHz;
- tracking the symbol frequency of TM-signal which modulates the signal of subcarrier frequency;
- extraction of convolution code symbols with authenticity evaluation (4 bits).

For doppler measurements the code values of frequencies of being received signal were stored with 1 s interval.

The IBM PC was aided to control the session and to indicate all the needed parameters, to receive data from the digital receiver with data quality estimation, to record the data on the hard disc with fixing to the time and to average the doppler measurement with 10 s interval

After session the comparison of data acquired from two semisets of the equipment was made and quality was estimated. The result was recorded into the flexible disk in the agreed format which is adopted in the DSN.

The data in accordance with the session of TM data reception from the s/c Voyager by the tracking station in Ussuriisk for the October 1992 are presented in Table 2.

Table 2.

Experimental sessions of TM data reception from the s/c Voyager.

N	Date	Session length, h, m	Useful data percentage	Outages
1	12.10.92	4.23	99.3	no
2	17.10.92	10.26	99.7	no
3	18.10.92	10.22	99.5	1 outage (2 min)
4	19. 10.92	11.22	89.1	1 outage (1 h 22 m)
5	20.10.92	10.22	99.8	no
6	21.10.92	10.07	99.8	no
7	22.10.92	9.06	99.6	no
8	23.10.92	10.02	99.7	no
9	24.10.92	9.52	99.7	no

10	25.10.92	10.32	93.5	1 outage (41 m)

All the sessions besides of the first one were carried out daily for 6-12 hours, therewith the average factor of using the prescribed session time was equal to 96.22%

As the data usage factor we consider the time when the authentical TM data have been received by the planned time of the session.

As the analysis of the JPL shows the TM data in all sessions were received with high reliability.

The data distributed according to the sessions of doppler measurements for the s/c Voyager are presented in Table 3.

Table 3.

Experimental sessions on measuring the doppler frequency of the s/c Voyager.

N	Date	Session length, h, m	Number of measurement
1	07.12.92	00.33	200
2	07.12.92	00.22	136
3	08.12.92	01.05	389
4	09.12.92	04.12	1512
5	09.12.92	02.25	869

The error of the range rate measurement on the basis of these data accounted 0.1 - 0.3 mm/s according to the JPL estimation.

In the process of arranging and fulfilment of experimental communication sessions with the s/c Voyager the russian and american sides jointly developed and refined the procedure of technological data exchange for planning and carrying out the communication sessions.