Low-cost ground segment for Russian Academia-University science space missions.

V. Nazarov[1] and R. Nazirov[2] and V. Gotlib[3] and O. Batanov[4] and N. Eismont[5] and V. Karedin[6] and F. Korotkov[7] and A. Ledkov[8] and Ya. Markov[9] and A. Melnik[10] and A. Tretiyakov[11]
Space research institute of Russian academy of sciences (IKI RAN), Moscow, Russian Federation, 117997

A. Popkov[12]
Laboratory of aerospace techniques (NILAKT ROSTO), Kaluga, Russian Federation, 248018

S. Svertilov[13]
Moscow state university, Institute of Nuclear Physics (SINP), Moscow, Russian Federation, 119992

The evident tendency is the rapid growth the number of microsatellites, and it's is fully explained by their low cost, the speed of preparation and relative simplicity of their realization. Quite often such spacecrafts are used in the educational purposes. At the same time the result of analysis shows that such satellites can also solve important fundamental scientific problems in addition to their educational purposes. But in this case it requires solving a number of additional tasks. First of all it is required to ensure comparatively high speed of the downlink telemetry for necessity of receiving of meaningful scientific results. That in turn is demanded the appropriate solutions in the on-board and ground segments of the mission. However it's necessary to save the main advantages of the microsatellites: low-cost of development, implementation and operations as well as short time of development. As an example, in the paper is considered the ground segment for Russian Academia-University microsatellite "Chibis-M" which is the first from series of the microsatellites "Chibis" used for solving different fundamental problems. The technical and methodical solutions, prospects for further development are discussed in the article.

I. Introduction

On November 2, 2011 cargo ship "Progress M-13M" was docked with ISS, it also delivered microsatellite "Chibis-M". At January 24, 2012 01:59 msk "Progress M-13M" was undocked and after two corrections it will be positioned at 500 km orbit. At January 25, 03:14 msk "Chibis-M" was separated and starts their flight. The mass of the microsatellite, is 34.4 kg, the mass of scientific instruments on board is about 12 kilograms.

The main purpose of "Chibis-M" is a comprehensive study of physical processes in atmospheric lightning discharges in a wide range of energies - from radio to gamma radiation as well as extended measurements of parameters which may be described by term called "space weather" [1-3]. It contains an impressive list of the scientific instruments which includes:

---

[1] Chief of laboratory, Laboratory of data processing systems, Profsoyuznaya St. 84/32 Moscow, Russia.
[2] Deputy Director, Profsoyuznaya St. 84/32 Moscow, Russia.
[3] Senior scientist, Exploration division, Profsoyuznaya St. 84/32 Moscow, Russia.
[4] Head of group, Laboratory of data processing systems, Profsoyuznaya St. 84/32 Moscow, Russia.
[5] Senior scientist, Dynamics division, Profsoyuznaya St. 84/32 Moscow, Russia.
[6] Lead engineer, SKB KP IKI RAN, Tarusa, Kaluga reg, Russia.
[7] Programmer, Laboratory of data processing systems, Profsoyuznaya St. 84/32 Moscow, Russia.
[8] Scientist, Dynamics division, Profsoyuznaya St. 84/32 Moscow, Russia.
[9] Programmer, Laboratory of data processing systems, Profsoyuznaya St. 84/32 Moscow, Russia.
[10] Head of group, Laboratory of data processing systems, Profsoyuznaya St. 84/32 Moscow, Russia.
[11] Programmer, Laboratory of data processing systems, Profsoyuznaya St. 84/32 Moscow, Russia.
[12] Chief of laboratory, Laboratory of aerospace techniques, Barrikad St 74. Kaluga, Russia
[13] Professor, Institute of Nuclear Physics (SINP), Moscow state university, Vorob'yovy hills, Moscow, Russia.

- X-ray gamma radiation detector,
- UV detector,
- RF analyzer,
- digital camera of optical range,
- a set of plasma-wave instruments.

These data will be used not only by scientists, but also by students and schoolchildren. Various educational centres: the Moscow Institute of Physics and Technology (Fiztekh) and, of course, Skobeltsin Institute of Nuclear Physics, Moscow State University (SINP MSU) will join the work with the Chibis-M satellite. In addition, at the frequencies of 145 and 435 MHz amateur radio network has begun to work, and even schoolchildren can connect to it.

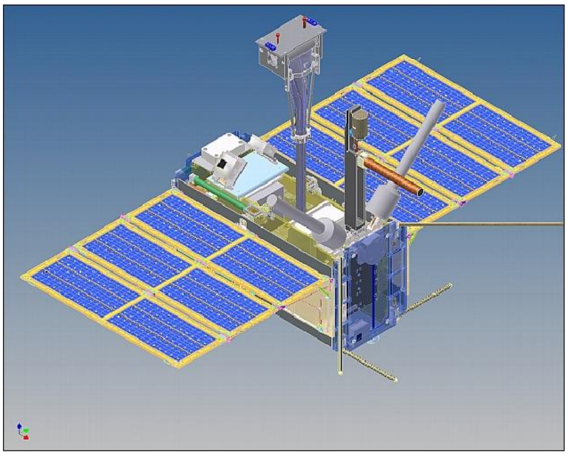

Figure 1 Microsatellite "Chibis-M".

Large scale of the measurements and fundamental science goals become it related with traditional "big" scientific missions. But, from other hand, budget limitations forced us to find some new technical and methodical solutions for building low cost ground segment with sufficient facilities.

II. Uplink and Downlink support.

Extended measurements means using of high-speed telemetry channels which requires respective power supplying. And it corresponds to some problems for relatively small spacecrafts. Therefore three downlink and one uplink systems (all systems have redundant channels) where used onboard spacecraft (see Fig.2).

High speed S-band channel (2270 MHz) which provides downlink in format of CCSDS telemetry packets up to 1 Mbps.

For technical mission operations radio-amateur bands are used with frequencies of 145 and 435 MHz for uplink and downlink respectively. For preventing of collisions with radio-amateurs and for safety reasons this links used security coding.

And at last the telegraph channel with simplest coding by dot-and-dash (Morse code) method is used for transferring information about the general status of the satellite. This link sends 16 housekeeping parameters such as onboard temperatures, voltages and so on. It must be noted that further to cheapest way (from view of power budget) to get the information about satellite's health this solution allows to involve a worldwide community of radio-amateurs for receiving it. On the web-portal of the mission the respective section was created and we receive more than hundred reports from radio-amateurs. Ant it was very significant assistance especially on the first stages of the mission where orbital parameters wasn't defined precisely yet and the onboard batteries wasn't fully charged.

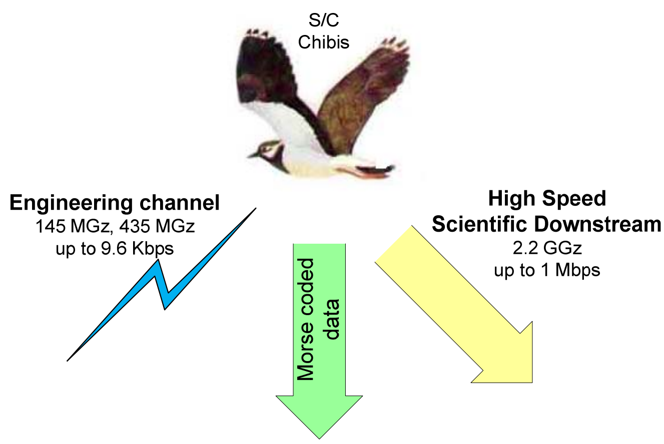

Figure 2 Up and Down-links in "Chibis-M" mission. (In Russian "Chibis" means lapwing)

The selected set of the channels described above allowed creating reasonable wide net of antenna systems (see Fig.3).

Thus for supporting the channel with technical information the station in Kaluga (with a few antenna systems) was used as main station. For widening working zone and for redundancy reasons the respective station in Krasnoyarsk University (SIBGAU) was used also. It's possible to extend the list of the such stations by using respective antenna systems placed in different universities (for example in Moscow State University) but as current experience shows it's enough for technological proposes even so for off-optimum situations.

For receiving of science data a few ground stations used also. The first one placed in special department of IKI RAN (Tarusa, Russia). Another one is placed in Etvos University (Budapest, Hungary) and also one in Panska-Ves, (Czech Republic). Because standard CCSDS compatible telemetry flow is used it's possible to extend the list of the station if it will be needed without serious costs.

And as was described above for receiving Morse coded data the radio-amateurs community was used with costs tents to zero.

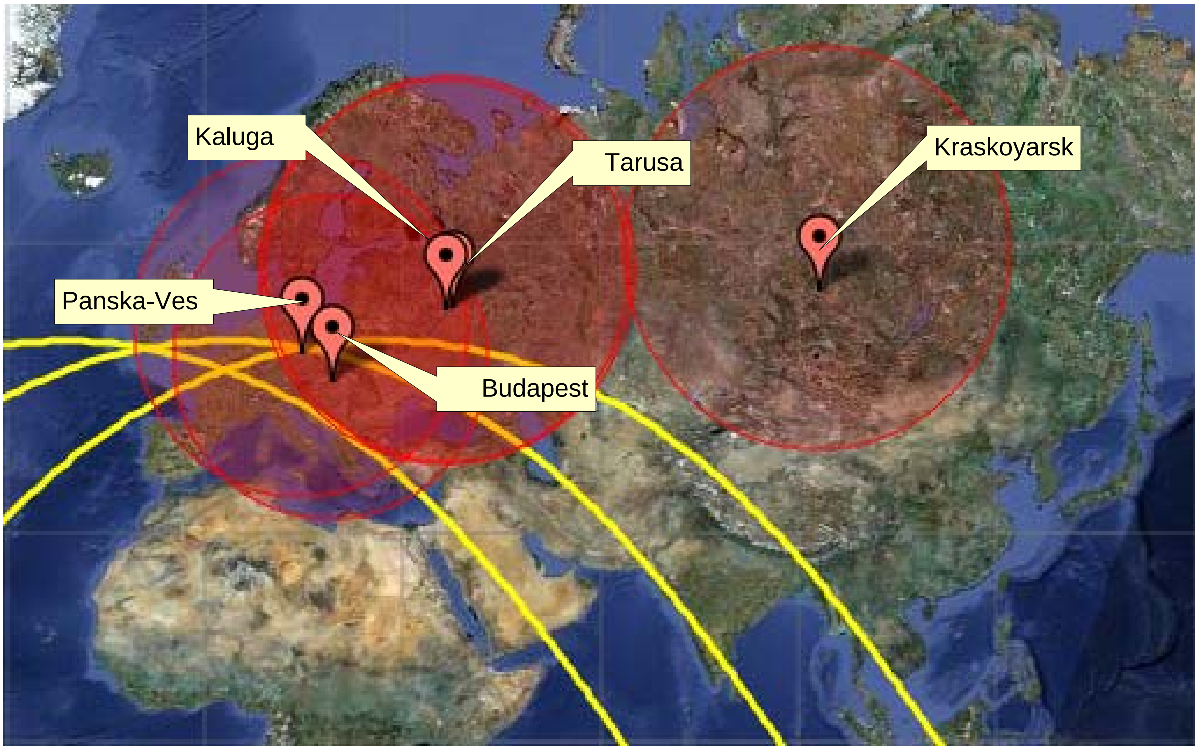

Figure 3 Ground stations map.

Generally this approach when existing nodes aggregated in the common net called overlaid net. And it allows to create principally new entity – ground net of the telemetry stations with minimal costs and efforts.

III. Principles of operations

As in other academia-university space projects some parts of satellite provided by industry. The "Chibis-M" mission was designed as base platform for prospective series of satellites for various space researches. And industry companies were involved in the project not as vendors only but co-designers too. By this approach innovation products were provided by the space industry. And it allows getting products with extended features on the background of reducing the cost. Of course it brings additional risks as some product was developed at first time (for example – orientation and stabilization system, provided by ScaNex company). For the compensation of risks the new approaches of mission operations were used.

As well as modern but with good success stories technologies [4-5] (for example Web 2.0) the new developmental approaches were used. Among these may be noted virtualization of the Mission Operations Center (MOC). By this approach the MOC is treated as distributed collaborative infrastructure. As contrasted to traditional dedicated MOCs a lot of routine work may be done by respective experts in comfortable environment and conditions. Extended telecommunication capabilities including videoconference facilities allow providing of collaborative work of geographically distributed specialists as common control team. Dedicated resources is needed only for time and reliability critically operations like receiving of telemetry information and data storing. This approach opens one of new and interesting ability, reasoning by analogy with "associated lunch" we may call it as "associated MOC". As was shown in [6] resources of the ground segments may be divided on three groups:

universal, space specific and mission specific. The paradigm used for “Chibis-M” design provides wide using of the common solutions. In other words series “Chibis” may be treated as aggregation of unified solutions. It means minimized constituent of mission specific needs. And in reality the MOC of the “Chibis-M” mission mainly uses communication and computing resources dedicated to other “big” science space missions. And as our experience shows this approach doesn’t brings serious additional troubles for missions operations. Quite the contrary, on the assumption of using unified technical strategy for design of ground segments for science space missions which provides succession of facilities described approach gives synergy effects for the all missions.

IV. Conclusion

The microsatellite “Chibis-M” is in flight operations stage now. Therefore it’s too early to make final conclude. Some used innovation approaches, for example principally new organization ideology where Science Operation Center (SOC) leads MOC isn’t described in the article and is waiting their evaluations. But on the base of experience of a few months of operations it’s possible to draw a conclusion that using of overlaid net of the ground stations and over-the-top services for operations (virtual associated operation center) may be just one possible way for deployment of fully functional ground segment for low budget science missions.

And it’s possible only in common technical policy used and continuity of the solution provided.

These approaches will be used for next microsatellites of series “Chibis” and we have preliminary agreement with different universities and academia institutes about building common ground infrastructure for low budget science-educational missions based on described approaches.

References

1. Angarov, V.N., G.K.Garipov, V.M.Gotlib, A.V.Gurevich, S.I.Klimov, V.G.Rodin, S.I.Svertilov, L.M.Zelenyi. Investigation of new physical phenomena in the atmospheric lightning discharges. Micro-satellite "Chibis-M". Small Satellites for Earth Observation. Digest of the 7th International Symposium of the International Academy of Astronautics (IAA), Berlin, May 4-8, 2009. Editors: Rainer Sandau, Hans-Peter Roeser, Arnoldo Valenzuela. Wissenschaft und Technik Verlag, Berlin, p. 69-72
2. Klimov Stanislav, Denis Novikov, Valeriy Korepanov, Andriy Marussenkov, Csaba Ferencz, Janos Lichtenberger, and Laszlo Bodnar. The study of electromagnetic parameters of space weather, micro-satellite "CHIBIS- M". Small Satellites for Earth Observation. New Developments and Trends. Rainer Sandau, Hans-Peter Röser, Arnoldo Valenzuela (Eds.). Springer-Verlag, Berlin Heidelberg, 2010. P. 95-102.
3. Klimov, Stanislav I., Gali K. Garipov, Vladimir M. Gotlib, Alexander V. Gurevich, Jean-Louis Pincon, Sergei I. Svertilov, Lev M. Zelenyi. The method of study in the ionosphere of the physical processes occurring in highaltitude atmospheric thunderstorms. 2012 USNC-URSI National Radio Science Meeting, TECHNICAL PROGRAM, HG1-7, p. 7, 4–7 January 2012, Boulder, Colorado, USA.
4. Nazirov R., Nazarov V. and Eismont N. Adaptation of modern methods and approaches of development and maintenance of information system for using in space missions. SpaceOps 2008 Conference. AIAA 2008-3299.
5. R. Nazirov, V.Nazarov, at all. Best practice patterns in design of the information systems for Russian scientific space missions.;AIAA-2010-2073 ; SpaceOps 2010 Conference
6. Nazirov R., Nazarov V., Eismont N., Some aspects of ground segment for prospective science space missions", Proceedings of the 7th International Symposium, «Reducing the Costs of Spacecraft Ground Systems and Operations (RCSGSO)» European Space Agency SP-648.