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Subject: Mars Together report and IAF paper
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Below is a report on the Mars Together 2001 study as it currently stands. This report was drafted by Vassili and I have provided some editing. This is intended to be the submission to the IJWG for delivery in December.

Please look over and markup areas which you feel are problems or potential disagreements.

This week we must produce a paper for delivery to the IAF by Oleg Papkov, one of the co-authors. I recommend we extract in whole, sections 1-3, 5 and 10 for the IAF paper, Comments?

Kat: Please prepare the paper (as listed above) in IAF format. This must be shipped to China with Frank Palluconi on Saturday, 5 October.

Lynn: Could you pull out appropriate figures for Kat to incorporate in the text? Many or all may be available in the engineering note by Bremenko.

Thanks to all,
Roger

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MARS TOGETHER 2001
JOINT US-RUSSIAN TEAM

Report to
US Executive Joint Working Group for Space Sciences
Section for Solar System Explorations
December, 1996

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1. introduction and Study Background

The Mars Together joint US-Russian study was established on 9 April 1994 by US and Russian scientific delegations meeting in Moscow. The delegations included representatives from the US National Aeronautics and Space Administration (NASA), the Russian Space Agency (RSA) and Institutes of the Russian Academy of Sciences (RAS). At the Moscow meeting, an agreement was forged to investigate cooperation in Mars exploration "with emphasis on the 1998 and 2001 launch opportunities." While the U.S. and USSR have collaborated in human space flight and Earth application missions, this is the first time in the history of cultural relations between our two countries that American and Russian specialists have been authorized to work together on a joint space science mission. The Jet Propulsion Laboratory is the principal contributor from the US side, while Lavochkin Association and IKI are the principal contributors from the Russian side.

Two technical concepts for joint mission to Mars in 1998 ("MT-98") were studied: (1) a stack consisting of a US orbiter with a Russian descent module, APS (Autonomous Propulsion System) and PROTON launch vehicle, (2) a scaled down arrangement based on the MOJ NIYA launcher. For a variety of reasons, neither of these concepts were adopted. But progress toward more intimate cooperation in Martian exploration was achieved: NASA invited Russian scientists to participate in US mission Mars Surveyor 98 missions and that invitation was accepted. V. Moroz is involved in the PM IRR experiment on the Orbiter, providing reflecting optical elements. V. Linkin will provide a Lidar instrument for lander. Earlier, there had been an agreement for cross participation in each others missions. This resulted in participation of US scientists in a few experiments on the Russian MARS 96. One US instrument (MOX) is incorporated in the MARS-96 small station payloads.

Hence the development of joint US-Russian exploration of Mars has been started, but on a more restricted scale than originally anticipated. Also, a new study was commissioned to investigate the possibility a combined US-Russian mission in the 2001 opportunity. A new US-Russian team to develop a preliminary concept was established by the Executive Joint Working Group on Cooperation in Space Science meeting in Moscow in October 1995. The new team is co-chaired by R. S. Kremnev (Lavochkin Association) and P. B. Ulrich

(NASA Headquarters). During the last year there were two meetings (February and June of this year, both in Moscow), several videoconferences, and exchanges of technical information via e-mail and faxes. Finally the basic option for a proposed mission (abbreviated below as MT 2001) was adopted. This option is described below.

The MT 2001 team began its work with a review of the factors that led to the demise of the ambitious MT 1998 ideas. It was concluded that a financially modest program with minimal demands on both countries, based on proven hardware, had the best chance for success. From the Russian side, this implied a mission concept that relied on the MOLNAYA, a launch vehicle with heritage extending back to the 50's and an exceptional record of reliability.

In spite of the failure of MT 1998 to produce a truly joint mission, the experience gained in that activity established working relationships that facilitated rapid progress toward an MT 2001 plan.

2. US and Russian National Programs

2.1 Goals

Mars Exploration was selected some years ago as a baseline Russian goal and has long been an important element of the US Solar System exploration program. Both Mars programs include as basic objectives the global mapping of the surface, long-term meteorological surveys, and first studies of the interiors. Both programs emphasize understanding the evolution of Martian volatiles and climate and the search of life (at least extinct, and possibly extant) as a key endeavor. Scientific topics include:

- A. Studies of the surface: tectonic and volcanic processes and products, crustal formation, weathering, ancient aqueous sediments, fluvial processes, aeolian processes, hydrothermal systems, and polar deposits, aging of rocks and geological formations.
- B. Studies of subsurface material: ground ice, composition of bedrock, possible subsurface organics, soil oxidation processes, and structure of the crust, mantle, and core.
- C. Atmospheric studies: present and past climate, trace gas abundances, stable isotopes, atmospheric escape rates, and global circulation and the forces that drive it.
 - 1). Life: search of areas where recent and/or extinct Martian biosphere could be found with highest probability, search of micro-organisms or their traces, products of their living activity, micro-fossils,

The history of water on the planet Mars was recognized as the key to the most of these problems.

The sensational discovery of possible traces of Martian micro-organisms in one of the SNC meteorites (McKay et al., Search for

Past Life on Mars: Possible Relic Biogenic Activity in Martian Meteorite
AL 1184001, Science, Vol. 273, pp. 924-930, 16 August 1996) has elevated the
importance of Mars studies as whole.

2.2 Current US Program

The US Mars program (Suppl. 1) has as an initial goal the recovery of the science lost from the failed Mars observer, [however, the US is taking an approach that differs from that followed previously]: It is embarking on a new program of a series of focused, low cost missions termed Mars Surveyor. The first element is the Mars Global Surveyor (MGS) orbiter which, along with the Mars Pathfinder lander, is to be launched in 1996. The Mars Surveyor program was introduced in February 1994 and authorized by the US Congress in the succeeding months.

After this, Mars Surveyor 1998 (MSP-98) orbiter/lander missions will be launched in 1998 and at least a MSP-01 orbiter and 2001. MGS, MSP-98 and MSP-01 are intended to recover the majority of Mars Observer global science and point toward the next step: Mars Sample Return. The US Mars exploration program is expected to proceed, and the details are currently under reconsideration. The Surveyor program goals may be accomplished by the US joining forces with international partners, the Mars Together 2001 concept being a prime example.

The first Mars Sample Return mission (MSRM) was planned on 2005, but after AL 1184001 discovery NASA is considering the possibility of doing it even earlier. It is expected that a sequence of MSRM will recover samples from different parts of Mars.

"To accomplish this strategic plan within a realistic budget, NASA is investigating the possibility of more international Cooperation in all Mars missions after 1998. Hence NASA is very interested in reaching an agreement about joint mission in 2001 as a prelude to more extensive cooperation in the future. US/Russia cooperation in MSRM also can be foreseen. Moreover MT 2001 may be one of the important steps on the way to MSRM.

2.3 Current Russian Program

The Russian government has approved a "Russian program of fundamental scientific research in space to the year 2000" (abbreviated below as RPFSS-2000), which includes two missions for solar system exploration. The first of them was planned for 1994 but postponed 2 years. It consists of an orbiter, two small landed stations and two penetrators. A second mission, originally scheduled for 1996, was cancelled.

There is no approved schedule in Russia for launches to the planets after 2000. However there are proposals of the Solar System Exploration Section of Space Science Council (Suppl. 2). These proposals confirm that Mars is the first priority goal for future planetary missions. They include three flights:

2001- with MARSOKHOD (a rover) as the main payload. "This MARSOKHOD is inherited from the original] y scheduled second RPSI-2000 Mars mission that was later cancelled.

2003- Phobos Sample Return mission.

2005- Mars Sample Return mission.

Cooperation with NASA in all of these missions is considered very desirable and important.

3. Rationale for Mars Together 2001 Mission (MT-2001).

3.1 Recommended MT-2001 baseline option.

A set of options for MT were developed by the US and Russian sides (see Suppl. 4). In June, one was selected for detailed study. This mission consists of two spacecraft:

SPACECRAFT I:
RUSSIAN LAUNCH VEHICLE [Molniya-Block 1,];
RUSSIAN DESCENT MODULE WITH MARSOKHOD ROVER
US PROVIDED CRUISE STAGE

US cruise stage provides power, attitude and trajectory control and communication for the descent module during cruise. The cruise stage is jettisoned from the descent module prior to entry.

SPACECRAFT II:
US LAUNCH VEHICLE [Delta 7325]
US AEROCAPTURE ORBITER

Aerocapture orbiter design is based on Mars Surveyor program 1998 lander design. It carries a gamma ray spectrometer, and IR spectrometer, and potentially additional instrument. It provides a relay for the Russian Marsokhod.

The concept for MT-2001 is shown in Fig. 1.

Orbiter and descent module with rover were important elements of the original Russian mission. The orbiter in the original all-Russian mission was designed primarily as a relay, in MT-2001 this function will be provided by US orbiters (MT 2001 plus possibly MGS).

An orbiter and lander were important elements in the original US 2001 plan. The Russian rover will provide some of the functions originally envisioned for a US lander.

3.2 Scientific rationale

The main elements in the MT2001 mission have been developed as a result of years of scientific planning. The orbiter payload of a gamma-ray spectrometer (GRS) complete the synoptic survey of the Martian surface originally planned for Mars Observer. An

infrared spectrometer will measure spectral details of rocks to find sedimentaries which will provide insights for future searches for extinct life by later missions. A similar process has taken place on the Russian side resulting in the payloads and missions for the rover. In addition to their own intrinsic scientific merit, an advantage accrues from the joint development of Mars Together: Scientific experiments on the rover from one side and the orbiter from the other will be complementary in their mutual attack on common scientific goals pertaining to the Martian environment. Furthermore, both parts of the mission may be scientifically reinforced by a possible exchange of scientists between the US and Russia.

3.3 Programmatic Rationale and Cost

The MT-2001 will achieve the scientific objectives for both Russia and the US at lower cost to both countries. For a fixed total cost the US can use one rocket instead of two and will not build a separate lander. Russia, on the other hand, can avoid the necessity to design and produce a new orbiter (the "classical" PHOBOS orbiter cannot be used with MOI NIYA).

The MT-2001 will be a combined international planetary mission involving Russian and US rockets, Russian Marsokhod and US Orbiter and cruiser.

The MT-2001 will also be the first experience for highly qualified US and Russian specialists in space science and technology to work together. It provides a perspective for more challenging future projects, such as Mars Sample Return.

3.4 The Political and Public Relations Effects

This joining of US and Russian efforts in a peaceful and scientifically important field will be a new step in the development of good relations between the two countries. It is likely to stimulate a positive public response in the US, where many people have a deep interest in planetary exploration. For people in Russia, such a joint project would be appreciated as a sign of the firm intellectual and technological status Russia enjoys in the new post-cold war world.

4. Technical Options for MT-2001 and Their Discussion

4.1 Basic Option Set

Originally four options were proposed for preliminary studies:

Option 1: RUSSIAN LAUNCH VEHICLE,
DESCENT MODULE WITH MARSOKHOD,
U.S. PROPULSIVE CAPTURE ORBITER.

Option 2: RUSSIAN LAUNCH VEHICLE,
DESCENT MODULE WITH MARSOKHOD
U.S. CRUISE STAGE
and
U.S. LAUNCH VEHICLE With
U.S. AEROCAPTURE ORBITER.

Option 3: RUSSIAN LAUNCH VEHICLE,
DESCENT MODULE WITH MARSOKHOD
U.S. LANDER
and
U.S. LAUNCH VEHICLE With
U.S. AEROCAPTURE ORBITER.

Option 4: RUSSIAN LAUNCH VEHICLE,
DESCENT MODULE WITH MARSOKHOD,
U.S. AEROCAPTURE ORBITER.

More detailed information is available in Supplements 2-3. The pros and cons will be discussed below.

4.2. Justification of baseline option choice.

Really there are two main types of options: single launch missions (options 1 and 4) and double launch (2 and 3). Single launch options are cheaper for US but require SOYUZ/FREGAT (which has not yet flown) from the Russian side as launcher. In contrast to SOYUZ/FREGAT the "classical" MOI NIYA with planetary block 1. (M-1'). below) was tested in many flights during 30 years for scientific, commercial and other purposes. For this reason M-1' was strongly recommended by the Russian side, for the MT-2001 mission. M-1' can deliver to Mars the stack of Russian descent module and U.S. cruiser but not full a scale U.S. orbiter. So the only option compatible with M-1' launcher is option 2.

This option gives the best balance of minimal risk and minimal cost for both sides and is simplest from the point of complexity of technical interfaces.

However both sides have in mind the possibility to rediscuss baseline option later if substantive progress with SOYUZ/FREGAT development is achieved in the next year or other factors lead to a better option.

5. Scientific Payload Elements of MT-98 Mission

5.1. Descent module.

The descent module will deliver the rover (Marsokhod) to the surface of Mars. The rover is under the technical responsibility of Russia.

Scientific experiments and instruments for Marsokhod were selected and recommended earlier by the International Scientific Committee of the Mars-94/96 Project. Their design and (in some cases fabrication) was started. A list of these earlier recommended experiments for the Marsokhod is given in Supplement 5. Modifications of this list are possible. For example, inclusion of new experiments (from the U. S.) in the rover payload would be possible, although restrictions in mass, volume and power are severe. The existing concept of the rover presumes its full mass will be about 100 kg, with a scientific payload of about 14 kg.

It is recognized by both sides that if the opportunity for US participation in the rover science materializes, a free and open process would be initiated in the US to solicit proposals. Following this process, a final recommendation will be agreed upon by both sides. A scientific conference on future Mars studies with emphasis on the rover mission will be held in early 1997.

One of the possible modifications to the current list of experiments is to remove from the rover itself all instruments that do not require mobility. It is conceivable that some could be placed on an immobile platform that will be the basic lander and starting base for the rover. Our current understanding is that first priorities should be given to scientific experiments and technical tools that are important for preparation to sample return mission. Even the use of 2001 Marsokhod direct for collection of samples which later will be taken to deliver on the Earth may be discussed.

5.2. orbiter

The orbiter payload will consist of a gamma-ray spectrometer (GRS) small TV camera and an infrared spectrometer. GRS will complete the synoptic survey of the Martian surface originally planned for Mars observer. The camera will provide a global monitoring of meteorological events and surface details variability. The IR spectrometer will measure spectral details of rocks to search sedimentaries on the surface. These places can offer some perspective for collection of samples with potential traces of extinct life.

Russian scientists may be involved in Orbiter experiments (GRS for example).

Much of the design of Mars 2001 Orbiter will be inherited from the Mars 98 mission.

6. Timeline for Mars-2001

The current timeline proposed for Mars-98 is given in Supplement 7. Launch is in February 2001 arrival at Mars in November.

The mission scheme is presented on Fig.5.

7. Interface control document (ICD).

Interface control document (ICD) for MT-2001 mission (base line option) was created jointly by both sides. It is presented in Suppl. 7. If the baseline option will be changed later the ICD content should be changed accordingly.

8. Cost estimates.

Preliminary cost estimates for Russia and U.S. are presented in Suppl. 8 and 9.

9. Open Issues for MT-2001

- a) A mutual understanding must exist regarding the decision making processes in both countries. Work should be started in early 1997 with adequate financial support to both sides. Final approval of the budget for the US 2001 mission will be made by the US Congress in mid -1997. An important step will be the June 1997 endorsement by the Gore-Chernomyrdin Commission which will be based on a summary report and other materials. The first phase of work (phase A/B in American terminology, "tekhnicheskoe predlozhenie" and "eskiznyi project" in Russia) should be completed by late 1997. It may be started immediately in January 1997, if the MT-2001 project is endorsed by the NASA and RSA.
- b) Launch approval. The Russian spacecraft contains a radioisotope thermoelectric generator (RTG). The US spacecraft does not include any nuclear materials. Previous studies reveal that the Russian planetary program has used RTGs and the Russians have a launch approval process which appears to parallel the US process in many respects. Discussions of the Russian process continue. From the information available to the team, it appears that any US launch approval requirements for this mission may be largely or totally satisfied by the Russian process. We expect that a deeper understanding of the Russian launch approval process will reinforce that conclusion and we recommend that substantive discussions between the US and Russia on launch approval proceed as soon as possible.
- c) There is a potential problem in the predicted strong seasonal winds in the northern hemisphere at the time of arrival. Current estimates of the wind velocities for this time are not compatible with the technical restrictions for Marsokhod and descent operations. Various so-

lutions will be studied: 1) Changes in the design of the descent elements and operation sequence, 2) Adjusting descent time to correspond to the predicted daily minimum of wind velocity.

10. Beyond 2001

A possible future cooperative projects after MT-200 1 was discussed tentatively. accepted by the study team in June. These possibilities include:

- Additional flights of the basic configuration planned for 2001.
- Phobos Sample Return
- Network mission
- Mars Sample Return

Both sides agree that sample return of extraterrestrial material has high scientific significance. initial discussions of possible joint Phobos and Mars sample return missions beyond 2000 were started.

Phobos SRM is one of the probable options for the Russian National program beyond 2000 (see section 2). The US position is that only a small US participation in the Russian Phobos SRM could be assumed at the moment.

The US side proposed a possible option of joint Mars SRM as an extension of the Mars Together concept. Russian specialists think that a Phobos SRM could be a useful precursor to the Mars Sample Return mission. Both sides plan to proceed with further options studies for both kinds of potential joint sample return missions, Phobos and Mars.

10. conclusion

The joint study results confirm that MT-2001 can be accomplished by the US anti Russia as a joint mission, if a decision process is started in December 1996 and culminated in June 1997. A draft summary, suitable for delivery to the Gore Chernomyrdin Commission, is given in supplement 9, Phase A/B of the MT-2001 project should be conducted in 1997.

FIGURE CAPTURES

1. Mars Together 2001 baseline option.
2. Marsokhod: the current conception.
3. Cruiser for MT-2001 baseline option: a tentative conception.
4. Orbiter for MT-2001 baseline option: a tentative conception.

5. Mars Together 2001: the scheme of mission..

1.1ST OF SUPPLEMENTS

1. U.S. Strategic plane of Missions to Mars.
2. Missions to planets in Russia after the year 2000:
proposals of the Solar System Exploration Section of the
Russian Space Science Council
3. Basic options set of the Mars Together 2001 mission.
4. Analysis of MI' 2001 options,
5. List of Earlier Recommended Experiments on Marsokhod.
6. Preliminary time line for MT-2001 (baseline option).
7. Interface control document (ICD) for MT-21101 mission (base
line option) .
8. Preliminary cost estimates of MT-2001 baseline. option for
Russia.
9. Preliminary cost estimates of MT-200 1 baseline option for
US.
10. Summary for senior management officials (draft)