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# Psychosocial Aspects of a Flight to Mars

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## Abstract

The first experiments modeling peoples' behavior during a long-term cosmic flight revealed the need for a more systematic monitoring of the development of the crew's mutual relationships, particularly in terms of collaboration and work-related communication. For this reason, in order to examine team dynamics, the sociomapping method was developed, which was first used in the HUBES 94 and ECOPSY 95 experiments. This method allows for an analysis and visualization of the continuous changes in communication and collaboration, including decreases in their quality and quantity. Sociomapping was used to monitor and analyze the communication and collaboration in simulations of flights to Mars in the Mars-105 and Mars-500 experiments. Based on the aforementioned experiments, it can be noted that statistically significant and nonrandom declines of the quantity and quality of team communication may occur during long-term missions, which may be related to changes in the team's performance. These changes are influenced by exterior stress factors, as well as cultural and linguistic differences and the length of the flight itself. In this chapter, the main findings of the experiment, as well as the resulting recommendations for a successful management of the psychological aspects of a flight to Mars, will be summarized.

**Keywords:** sociomapping, crew communication, psychological preparation, psychological support, debriefing, monitoring

## 1. Introduction

During the preparation of the first cosmic flights, the main question was their technical feasibility, which was first positively answered by the German rocket scientist Wernher von Braun. His technical feasibility study [1] had originally been an attachment to the science fiction story of a journey to Mars, which he wrote during his postwar internment [2]. In his story, he makes the crew members go through a 1-month isolation prior to their flight to Mars, in order to let this character screening test verify their ability to manage psychological distress [3]. When he modified this story for Collier's magazine edition, he writes about how states of tension and hatred appear among the crew members after several months, which could even have led to murder [2]. At this time, researchers were not only interested in physiological questions anymore but also in psychological aspects of extraatmospheric flights [4]. In the years 1956–1958, the first simulations of a stay in a cosmic cockpit took place, which included not only physiological but also psychological monitoring [5]. During one of these experiments, a decline in performance and mood was observed. Due to displays

of hatred toward the researchers, the question arose whether to prematurely end the week-long isolation study [6]. The founding of the National Aeronautics and Space Administration (NASA) in 1958 allowed the extension of the experimental research program, including psychosocial aspects of long-term space flights. The psychological prerequisites for managing a cosmic flight were also considered important during the selection of the first astronauts in the Mercury project—besides an interview, as well as personality and performance psychological testing, candidates were sociometrically questioned, including whom of their colleagues they would commission to fly if they themselves could not and with whom they would most like to undertake the flight if the crew only had two members [5]. In his summarizing study, Christensen [7] reverted to the progress and results of this selection, to the existing interpersonal antagonisms, as well as to other findings. In explicit relation to the preparation for a flight to Mars, Christensen wrote about the need to research the impacts of cosmic flights on human behavior. Chambers [8] reached the conclusion in his summarizing study that psychological variables have a greater impact on the progress of simulated flights than physiological variables do. He also concluded that over time, motivation may decrease and that some crew members may become more irritable, even hostile. According to him, this can be prevented not only through a selection of suitable, i.e., stress-resistant, individuals, but also through training, which should include the team's isolation before the flight. In 1963, the Institute of Biomedical Problems (IMBP) was founded in the Soviet Union, whose purpose was to deal, among other things, with the research of the conditions of a flight to Mars [9]. In 1964, the first experiment took place in the IMBP—a 120-day-long stay of a three-member crew in a module imitating a spaceship designed for a flight to Mars [10, 11]. Following up, an experiment of a 1-year isolation of a three-member crew took place in 1967–1968 [11]. As one of the participants of this 1-year experiment later indicated [12], it turned out that “the problem of the crew's psychological tolerance is one of the key problems of the medicinally psychological assurance of lengthy cosmic flights.” Fraser [13] analyzed 60 confinement studies and also reached the conclusion that feelings of anger and animosity, directed either at other crew members or at the researchers and other outside persons they communicate with, occur frequently. Haythorn [14] indicated in his summarizing study that interpersonal relationships do not always alleviate stress but can also produce it. Furthermore, he notes that little is known about the behavior of isolated groups in stress situations, due to the lack of longitudinal studies. As Suedfeld [15] later pointed out, it is possible to deduce, to a certain extent, the behavior of people on long-term cosmic missions from early terrestrial and marine exploration voyages, which also illustrate the importance and vulnerability of mutual interpersonal relationships. Kanas and Feddersen [16] conducted their review bearing in mind the fact that the mission to Mars will be a long-term one. Among other things, they point out that in the longer term, restrictions of interpersonal contact may appear. Like other similarly oriented research, they recommend reducing the risks with a suitable selection of people and with activities compensating the monotony and sensory deprivation. Vinograd's work [17] was a synoptical summarization in its time, comprised of 14 studies simulating cosmic flights but also of comparable studies of submarine crew members, teams in arctic or military environments, or in other situations of isolation. An analysis of individual studies reveals not only the importance of mutual relationships but also the lack of tools for a continuous (quantitative) capturing of their changes. In 1975, the newly founded European Space Agency (ESA) joined the other research institutions in their coverage of cosmic research (including psychosocial questions).

## 2. Deepening of the research on psychosocial factors

During the 1970s, it was proven during real cosmic flights that relationship and communication issues can have grave consequences. In 1974, the first cosmic strike of a crew led by William Pogue took place, who reasons in his autobiography [18] that the strike happened due to the demanding work program, which did not include time for rest. The exhaustion culminated in a conflict between the control center and the astronauts, to which the astronauts reacted with a 24-hour silence. In 1975, the astronauts themselves pointed out the importance of the psychological aspect of space flights [19]. In 1976, a premature abortion of the mission of the two-member crew of Volynov and Zholobov occurred, which was later attributed to the demanding work conditions, the worsening psychological state of the crew, but also to the serious conflicts between the two astronauts [20, 21]. Almost 10 years later, Harrison and Connors [22] suggested lowering the psychological and interpersonal vulnerability of the team not only by a suitable selection of crew members but also through training in group dynamics and by offering psychological support. They request that the anecdotal testimonies of the importance of these factors be examined by systematic scientific research. In cooperation with the IMBP, the Štola 88 experiment was conducted in the former Czechoslovakia, in which the comparison of two teams simulating a flight to Mars showed how differently the communication can develop during isolation depending on the composition of the team and leadership type [23–25]. In this 23-day experiment (structured for the crew as thirty 18-hour days), it was shown, among other things, that part of the tension manifested itself in a deterioration of the communication with the control center [24, 25]. In a later debriefing, the presence of a woman in one of the teams was mentioned as positive [26]. Related to the renewed considerations of a journey of six (or more) astronauts to Mars, Kanas [27] points to the possible impact of psychological, psychiatric, and interpersonal factors on the safety and success of such a mission. He mentioned interpersonal tension, a continuously decreasing team cohesiveness, the need for privacy, and the leadership's contradicting focus on the task and on emotions. In the 1990s, under the tutelage of the European Space Agency, a 30-day experiment with a six-member crew, Isolation Study for European Manned Space Infrastructure (ISEMSI-90), was carried out [28], as well as a 60-day experiment with a four-member crew, Experimental Campaign for the European Manned Space Infrastructure (EXEMSI-92) [29]. To capture the relationship dynamics, the Systematic Multiple Level Observation of Groups (SYMLOG) method [30, 31] was utilized, for example, as well as an analysis of spatial behavior [32, 33] and an analysis of the communication with the control center [34, 35]. During a summary of the EXEMSI experiment's results [36], it was noted that while no conflicts occurred within the team, this came at the expense of suppressing affection and a more rigid functioning of the team. Cazes and his colleagues believe that it was possible to maintain such a communication thanks to the experiment's relatively short duration and to the absence of any real risk. They consider this type of behavior inadequate (even dangerous) for a real space flight. They also point out that the team's cohesiveness was maintained by using the management as a scapegoat, as demonstrated by the criticism of the ground crew during crisis situations. For this reason, Cazes et al. [36] have doubts whether the harmony presented in sociometric tests was real or apparent. An important stimulus for the research of communication in the 1990s was the analyses proving that a majority of accidents in aviation are caused by human factors [37]. As it later turned out, after the introduction of standardized communication rules (the crew management system), accidents caused by human factors decreased significantly [38]. In 1994, a joint project



between the ESA and IMBP was carried out, the Human Behavior in Extended Spaceflight (HUBES) experiment, in which a 30-member crew was isolated for 135 days. In this experiment, physiological variables were observed in addition to the crew's communication. Sociometric tests were included, as well. The sociomapping method, which had been tested for a year on military units of the Czech army [39], supplemented the data collection and will be presented in more depth in the following chapter. In 1996, a 30-day stay of a four-member crew took place as part of the Lunar-Mars Life Support Test Project [40]. Even though the team dynamic was evaluated as ideal during the debriefing of this experiment, one of the recommendations was for the teams to be briefed more and sensitized to the psychological aspects of the experiments. In the summary of the subsequent 91-day experiment that took place in the Lunar-Mars Life Support Test Project in 1997, its leader mentions that in the early phases of the project, miscommunications occurred between the control center and the crew [41], to which it was necessary to react with an increased emphasis of the "overall team-integration approach," which also included members of the management. Holland and Curtis [42] pointed out in their summary of the results of NASA studies within the Lunar-Mars Life Support Test Project that extending the length of the mission increases the significance of psychological factors and thus psychological activities, as well, which are meant to ensure the success of the mission [43]. Among those, they mention training, briefing, in-mission tracking, and prospective interventions. They also allude to the importance of communication with the family and other close people outside of the crew. As Galarza and Holland [44] propose, the fact that teamwork and the ability to get along with the team are critical competencies for long-term flights should be reflected in the development of tools and procedures for the selection of people but also in their trainings and in-flight support. Despite the knowledge that tensions may rise during periods of isolation and partial communication isolations of certain team members may occur, the next experiment conducted in the IMBP, Simulation of Flight of International Crew on Space Station (SFINCSS), was carried out without a continuous monitoring of the communication. Furthermore, it utilized subjective evaluation scales and did not provide an appropriate training on group dynamics, which would include cultural and gender aspects, too (a woman took part in the experiment, unlike the previous HUBES and EKOPSY experiments). The experiment had to be terminated prematurely due to an argument between two astronauts, resulting in a physical altercation, an allegation of harassment, and due to the explicit request of a Japanese crew member to be able to leave the shuttle [45, 46]. Despite its failure, this experiment was useful, as it pointed out what consequences an underestimation of a continuous monitoring of communication and its subsequent interventions can have. It also demonstrated that it is necessary to pay attention to linguistic and cultural aspects. Morpew [47] refers to personal conversations with astronauts Jdanov and Atkov to point out that the astronauts themselves consider psychological and psychosocial aspects among the most critical problems of long-term flights, based on their own experience. Among the most significant psychosocial stress factors, Morpew mentions the high demands on team coordination, tensions between the crew members and control center, the forced contact with other crew members, the lack of contact with the family, cultural differences, and other factors, such as differences in gender, personalities, and others. Other non-psychosocial factors, such as high or low workloads, lack of privacy, space adaptation sickness, and of course the permanent life-threatening dangerous environment, must be considered, as well. Morpew [47] concludes that the US cosmic program considers psychological factors critical for increasing the safety and ensuring the success of the mission. In 2004, Manzey states that the research on human behavior during long-term missions is still insufficient to

estimate and reduce specific risks associated with a long-term journey to Mars. In this context, he mentions that it is necessary to pay attention not only to an individual adaptation and performance but also to the interactions among the crew members and methods of psychological measures [48, 49].

### **3. Sociomapping the communication of the crew on a flight to Mars**

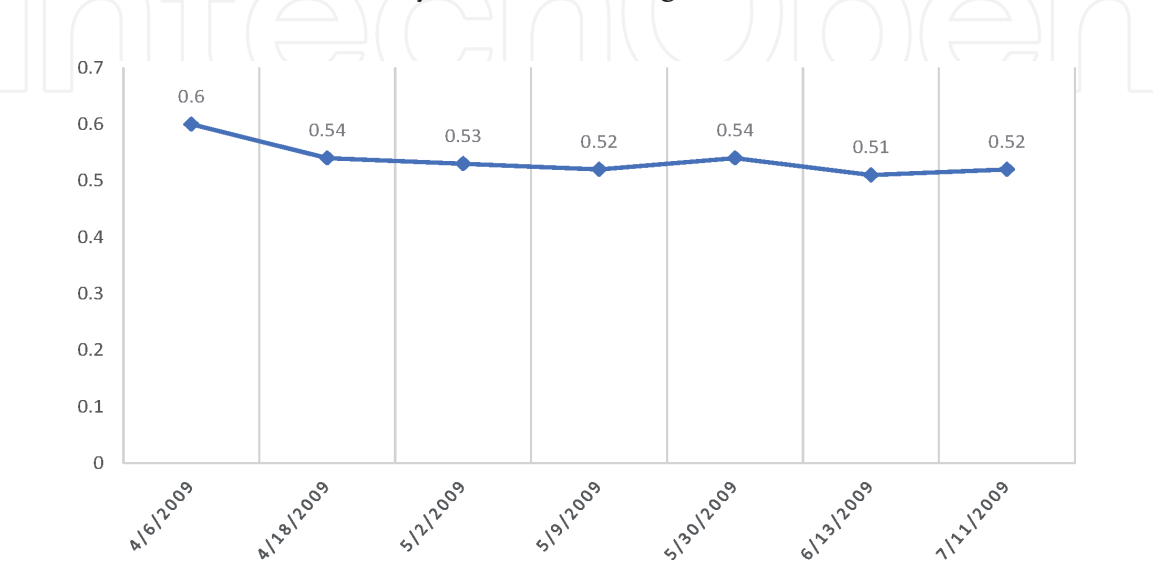
The sociomapping method allows to visually express mutual proximities (and distances) between individual teammates, military units, and crews [39, 50–52]. From a mathematical perspective, proximity is the degree of membership into the fuzzy set of people close to a specific member of the team. Various operational definitions are being used for the degree of membership, depending on the situation. Mutual proximity can be defined by the time spent on joint conversations, the volume of text or information, the average physical proximity, and many other characteristics. Most commonly, scales evaluating the mutual communication or cooperation in a given timeframe from a quantity and quality standpoint are used [52]. Such operationalized values of mutual proximity do not have to be symmetrical for two team members. Data about the validity, reliability, and time dependability is known and constantly being supplemented [52–55]. During the creation of sociomaps, the order of the closest to the furthest colleague is correlated for each team member in terms of the spatial distance ranked by the closest to the furthest according to the degree of membership. The final sociomap is created by maximizing the average Spearman correlation coefficients calculated for each team member [51, 52, 56]. During sociomapping, the average values of the scales are being monitored using the control chart method, which allows to capture significant deviations over time [52, 57, 58]. In the HUBES experiment, it turned out [23] that sociometric tests were not sensitive enough, whereas the scales evaluating the cooperation allowed to capture the gradual development, which consisted in one crew member separating from the other two with a simultaneous decrease in communication (substantiated by analyses of actual communication). The aggregated score expressing the degree of subjectively and physiologically captured stress grew over time, particularly in the final quarter of the experiment [23, 50]. As (not only) the HUBES experiment showed, traditional sociometrical procedures consisting in the selection of the remaining crew members are not very suitable due to their lack of sensitivity to continuous changes, which is particularly important in long-term missions. For this reason, sociomapping was also used in the 90-day experiment ECOPSY-95, in which a three-member crew was expanded by another three-member crew over the course of the experiment. Thanks to sociomapping, it was possible to capture how both crews interconnected from a communication standpoint, particularly thanks to the communication between the two crew leaders [51, 59]. After the departure of the second crew, the original three-member crew returned to the initial composition, while one of the members remained relatively separated from the communication perspective. In the Mars-105 experiment, a flight to Mars was simulated throughout a 105-day stay of a six-member crew in a module of the MIR ship [52]. To monitor the communication, subjective scales were used again, including a five-point evaluation of changes in the communication frequency with individual crew members, for example, the communication in the last previous weeks decreased significantly – decreased slightly – stayed the same – increased slightly – increased significantly. In addition, it included a five-point evaluation of the required optimal change in communication frequency (a wish for a significant decrease – slight decrease – maintenance of the current state – slight increase – significant increase), a percentage evaluation of the quality of cooperation with

individual team members (0–100% scale), as well as an overall assessment of the team’s performance and atmosphere (0–100% scale). The scales were supplemented by a question about the frequency of misunderstandings. All questions concerned the period from the previous measurement (i.e., approximately the prior 2 weeks). The following graph indicates the average values of the five-point scales of the perceived communication changes converted to the interval <0;1> for seven specific dates indicated by the administration (the whole experiment took place between March 31, 2009, and July 14, 2009). The value of 0.5 corresponds to constant, or stabilized, in terms of communication frequency (**Figure 1**).

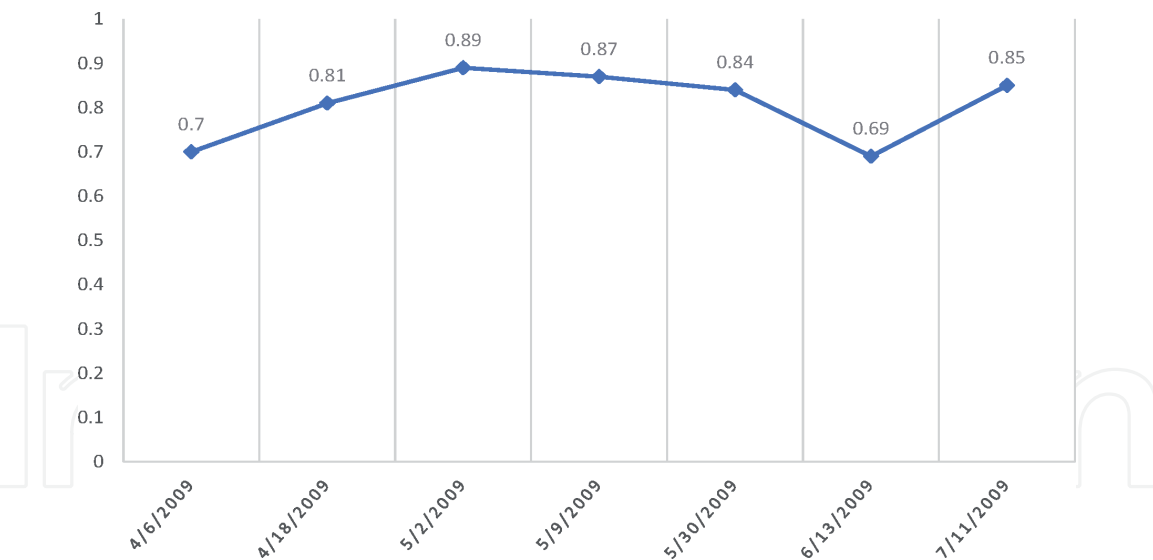
Even though the communication frequency stabilized throughout the experiment, it is possible to capture significant changes in the percentage scales of the assessment of the mutual communication’s quality, which match the fluctuations of the average percentage scales of the overall evaluation of the team’s performance and atmosphere (**Figure 2**).

In the mutual assessment of the communication quality and in the overall evaluation of the team’s performance and atmosphere, the minimum was reached in the administration on June 13, 2009, i.e., about two thirds into the experiment. The assessment of the performance and quality of communication were even lower at this point than it had been during the first administration. Furthermore, for this period, the highest number of misunderstandings was reported (only two out of six people indicated that no misunderstandings occurred in this period). In a personal account, the crew’s leader commented on the worsening atmosphere, performance, and quality of communication. Among other factors, he considered fatigue, as well as the suggested improvement measures, which the crew submitted to the control center and which were not accepted according to their expectations, to have played a role. The deterioration of communication quality, captured on multiple levels, proves that it is possible to detect significant changes using a scaled assessment, even though the scales are test–retest reliable. The median of the test–retest correlation in this experiment was 0.8 [52]. While the average scale values may point to the fact that the communication overall is deviating from its norm, the sociomaps offer insight on an individual team member level. The following figures show sociomaps of the crew (including the displayed position of the control center) dated May 2, 2009, and May 9, 2009 (in this case, the time passed between the administration was only 7 days) (**Figures 3 and 4**).

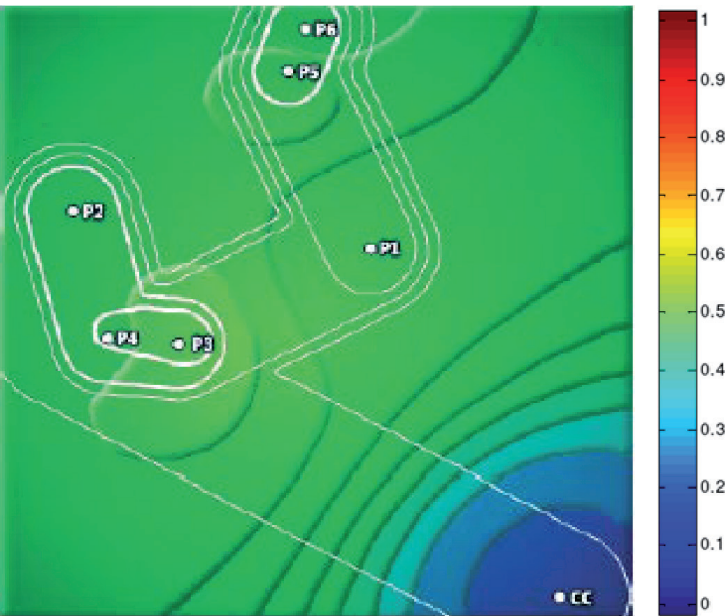
As the description of sociomapping above implies, the closer two crew members are to each other, the more they communicate together. The whole team can be



**Figure 1.**  
*Average change in frequency of communications.*



**Figure 2.**  
*Average quality of cooperation.*



**Figure 3.**  
*Sociomap of Mars-105 crew (May 2, 2009).*

divided into subsets according to their mutual adhesion [50–52]. The blue arrows indicate a desired increase in communication (compared to the current level), while red arrows signify a wish for the decrease of communication. Colors stand for the average frequency of current communication for each crew member and control center (CC).

The situation changed over the course of 7 days—person P2 is more connected with persons P3 and P4. The basis of the second subgroup is primarily the close relationship between P5 and P6, the only foreign (non-Russian) crew members. Following the Mars-105 experiment, the longest experiment to date took place, lasting 520 days—Mars-500, during which communication was also continuously monitored. Mars-500 simulated a flight to Mars in the full scale of its estimated 520-day duration [57, 60]. Sociomaps were continuously sent to the control center. The option of notifying the center about unusual or unexpected situations for possible intervention purposes was not utilized in this case, as the communication was relatively stable throughout the experiment, both in terms of quantity and quality.



The entire communication progress may be viewed dynamically based on individual sociomaps created in regular 14-day intervals (36 administrations in total). The simulated landing on Mars occurred in February 2011, when the team was separated into two subteams—a landing and orbital team. Control center is included (Video 1 can be viewed at <https://bit.ly/2ENYzja>).

Even though the average correlation between the values of subsequently occurring sections was high (the average scale value of the test–retest 14-day correlation was 0.785 for the current communication and 0.843 for the optimal communication), a decrease could be observed in some cases. The test–retest correlations for the 16th and 17th collection, which took place before and after the landing, were  $-0.005$  and  $0.117$ , respectively [60]. Since each of the six crew members expressed their opinion about the remaining five members in the relational questions, 30 values were gathered in total in the individual collections. The following graph (Figure 5) shows the differences in absolute values between the actual degree of communication expressed on a five-point scale and the optimal communication value.

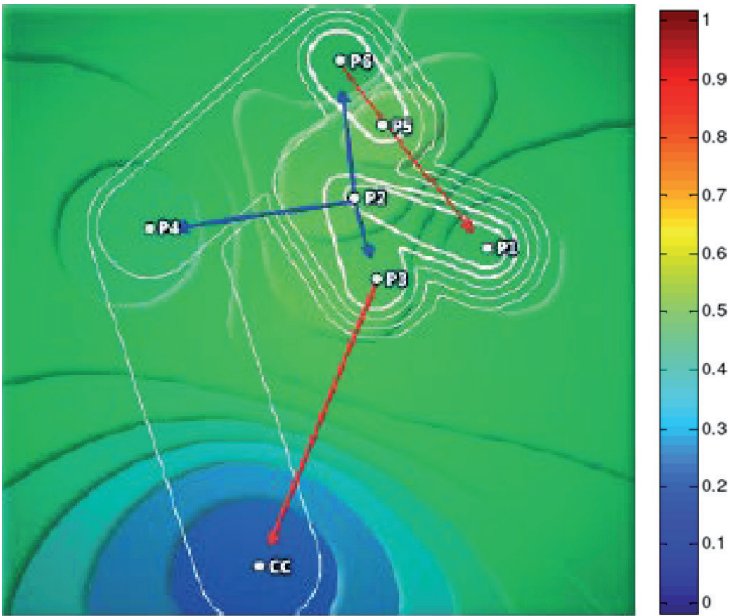


Figure 4.  
*Sociomap of Mars-105 crew (May 9, 2009).*

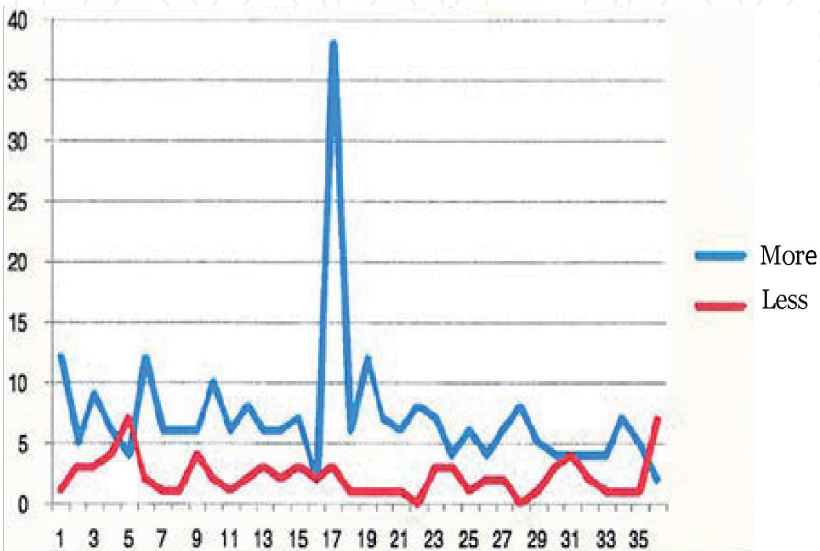
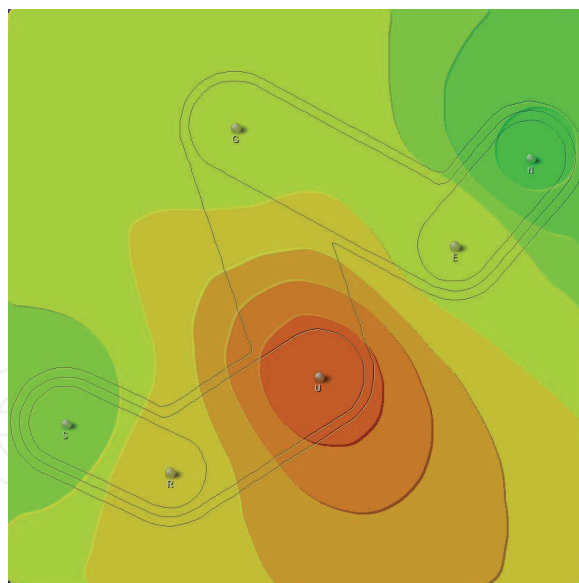


Figure 5.  
*Differences between current and optimal communication in Mars-500 experiment.*



**Figure 6.**  
 Aggregated sociomap of Mars-500 experiment.

The most visible change occurred during the landing period. The occurrence of misunderstandings negatively correlated with the overall level of current communication ( $r = -0.33$ ), while it positively correlated with the expressed wish for a communication change ( $r = 0.42$ ). Besides creating partial sociomaps, it is possible to aggregate the sociomap data, as well as that from the derived sociomap, for an extended period. That way, it is even possible to aggregate all 36 data collections into one sociomap expressing the interconnectedness of the individual crew members (**Figure 6**).

The main linking factor among the crew members is person U, who is closer with pair R and S. The triplet U, R, and S, as well as G, E, and N, forms the Russian and non-Russian team subgroup, respectively. Communication within these subgroups is statistically higher than communication between (people from) both subgroups ( $p = 0.002$ ,  $d = 1.28$ ), which accentuates the importance of understanding linguistic and cultural aspects of communication and cooperation in crews. The Mars-500 experiment showed that this way of monitoring is sensitive enough (despite the high test–retest reliability of the scales) and that the crew can handle communication even in such long isolation periods without long-term deterioration. Based on our experience and research, we assume that monitoring alone can sensitize the crew to the importance of communication and instigate possible attempts to change this communication.

The advantages of monitoring communication using sociomapping continue to be examined in other experiments simulating space flights [61–63]. The interventions' success is being researched experimentally and quasi-experimentally within work teams [53, 64–68]. The main source of our findings is all work teams we supported with sociomapping, some of which were being examined over the course of more than 3 years [52]. The second significant source is the usage of sociomaps in the Czech Army, where this method has been used in combat teams for 25 years [69].

## 4. Conclusion

From the experiments to date, which directly or indirectly simulate a flight to Mars, it can be deduced that psychosocial factors are critically important and their underestimation may even lead to a failure of the whole mission. Besides selecting

suitable, stress-resistant individuals during the preflight phase, it is recommendable for the crew members to meet well in advance and for them to spend some time together in isolation before the actual flight. During this phase, it would be appropriate for the crew to be briefed with the issue at hand and with the usual development of the group dynamic, the methods that will help them capture it, and with the subsequent procedures of formulating a contract about what can be improved based on this data. We also recommend paying attention to a sensitization on cultural, linguistic, and gender aspects during the training and briefing prior to the actual flight. We also suggest for the team to familiarize itself with the way of conducting the debriefing, which improves its communication and performance. This is based not only on the meta-analysis, which showed a significant increase of the performance of teams that conduct debriefings [70], but also from the derived recommendations aimed specifically at space flights [71]. In the view of the communication delay between Earth and Mars, it is necessary to support the teams by leading them to conduct the debriefing based on an automated, structured protocol. For example, this could be sociomapping followed by a debate about how the communication is going and how it might be continuously improved. Throughout the mission, we recommend a regular monitoring of the communication with a possible discussion on improvement options. From time to time, the team “on Earth” should be included in such a discussion, so that this intervention can help strengthen the mutual ties and reduce the risks of possible displacement. Besides a debriefing, providing support or an intervention may also be considered in more difficult times. We also unequivocally suggest that the contact with close friends and relatives be available, which will decrease the sense of isolation. Monitoring communication using the sociomapping method will continue to be a part of the experiment in the Sirius project. After the Sirius 2017 [72] and Sirius 2019 experiments, the utilization of sociomapping is planned in the Sirius 2020 and 2021 experiments, as well. The team led by Kateřina Bernardová is now preparing not only a methodology of the measurement itself but also a methodology of team dynamic training and subsequent interventions similarly to the way the Czech Army has been using the system for the last 20 years [69].

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