

**Protocol of the meeting on the further development of the NSFC-RSF
cooperation project "Stability and control of experimental closed ecological
systems of human life support: data analysis and mathematical modeling"
between China and Russia**

In Krasnoyarsk, after five days of project exchanges and in-depth discussions between the Chinese and Russian teams, the following consensus has been reached on how to further carry out the research of this project and the next cooperation:

1. Based on the configurations of Bios-3 and Lunar Palace 1, the plant unit is common to both sides and is the most important unit constituting the system. The model of the plant unit determines the effectiveness of the joint model. Therefore, the model of the plant unit will be studied jointly by both sides. The two sides will jointly discuss common state variables, rate equations, and appropriate parameters of the model. The plant unit model will be the common research result of both sides.
2. The unique unit of Bios-3 is microalgae, and the unique unit of Lunar Palace One is solid waste and insects (*Tenebrio molitor*). For their respective unique units, their models will be completed independently by each side. Then they will be coupled to the model of the plant unit.
3. Combine each unit organically through a pool bus structure to form a dynamic model of the joint system. The research goal of both sides is to obtain a unanimously recognized dynamic mechanism that drives the operation of the entire joint system. Its dynamic behavior may allow some deviations from experimental data.
4. The next research of both sides will be based on the above 1-3 points of consensus, and carry out research independently or in cooperation. In the process of cooperative research, both sides will share their respective data for model parameter estimation and validity testing. The results formed will be jointly signed and published in papers.
5. Waste treatment and subsequent plant food production play a key role in the material cycle of the biological life support system (BLSS). Improving this process will greatly promote the closure efficiency and stability of BLSS.
6. The processing methods of the Chinese and Russian teams have their own characteristics and complement each other. The Chinese team, before planting, processes human waste and plant straw by high-temperature mixed fermentation and then uses earthworms to form a substrate. The Chinese team also has experience in creating engineered bacterial communities that promote plant production and fermentation of solid waste. The Russian team has two approaches: physicochemical - "wet" combustion of human metabolic waste, thus obtaining mineralized solution and sediment, which are used in a neutral substrate for growing plants; and biological - composting plant waste in a soil-like substrate (SLS) using earthworms and a community of substrate microorganisms. Russian approaches can be used both independently and in combination: composting plant waste in SLS with the introduction of mineralized solution and sediment after "wet" combustion of human waste. The two teams can further consider the stability of the system by comparing different treatment methods, such as plant production efficiency, element circulation status, and microbial safety.
7. Both the Chinese team and the Russian team have their own small unmanned systems that can be used to study the above points and have a good foundation. Both teams can deeply explore the treatment process of human waste and plant solid waste using a small closed system without

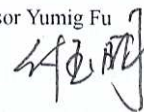
- human participation and compare the stability of the system under different treatment methods, in order to perfect treatment processes and construct a mathematical model for human waste and plant solid waste.
8. This work will become the key content of cooperation between the two teams in the next two years and lay an important foundation for the application of the next cooperation project. The specific research content in the near future can be carried out along the following lines:
- A. Using a small unmanned system to observe the substrate prepared from waste by different treatment methods. Planting at least five generations of plants represented by wheat and monitor the plant production status and system stability during the circulation process.
 - B. Analyzing the dynamics of microbial communities by means of molecular biology and culture groups, including the presence or absence of bacterial biomass harmful to plants and microbial resistance genes, toxin gene accumulation, etc., and exploring the role of microorganisms in system stability.
 - C. Establishing an appropriate engineered artificial bacterial community to improve stable solid waste treatment and plant production and maintain the stable state of the system.
 - D. Assessing the efficiency of using artificial bacterial community in waste processing: a) Chinese method, b) Russian physical-chemical method; c) Russian biological method and d) combined Russian method.
 - E. Combining the experimental results of both teams to perfect treatment technology and a mathematical model for human waste and plant solid waste and provide the basis for the construction of the biological regenerative life support system of the future lunar base.
9. To apply for the next project, both teams propose to use "theoretical and experimental analysis of promising technical methods for the participation of human metabolic products in the cycle of BLSS" as part of the content, mainly including:
- A. Conducting a comparative analysis of known and newly proposed treatment schemes and solutions for human waste under BLSS conditions.
 - B. Conducting experimental verification of promising biological, physicochemical and combined methods for processing human waste products, applicable to BLSS.
 - C. Based on the analysis of the obtained results and considering its possible application in long-duration lunar stations and bases, putting forward suggestions and recommendations for implementing the technical scheme of incorporating waste products into the cycle of BLSS.
10. Based on the above 5-9 points of consensus, the two teams will work together to carry out research and jointly sign and publish results to promote the successful conclusion of this project and lay an important foundation for the application for the new project.

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