Method for analyzing dynamic loads on items of mass during an aircraft emergency landing

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This method was developed within the framework of the *Energia-Buran* project in 1983-1987. It is based on the finite element method (FEM). A detailed description is given in the author's PhD thesis:

Spirochkin YK (1987) Metodika raschyota dinamicheskogo nagruzheniya gruzhov pri avariinoi posadke letatelnogo apparata (Method for analyzing dynamic loads on items of mass during an aircraft emergency landing). Dissertation, NPO *Energia*, Kaliningrad, Moscow region, 1987 (Defended in the Central Institute of Mechanical Engineering (TsNIImash), Kaliningrad, Moscow region, 1988).

Content of the dissertation is as follows:

Introduction
Chapter 1 – Mathematical modeling of a system: "aircraft – item(s) of mass – landing surface"
 1.1 Features of the loading process for the aircraft structure, payload and other items of mass during an emergency landing
 1.2 Finite element discretization of the aircraft structure
 1.3 Modeling of the landing surface
 1.4 Modeling of payload and other items of mass
Chapter 2 – Analysis of the system dynamics
 2.1 Dynamic equilibrium equations
 2.2 Basic relations for beam finite elements
 2.3 Basic relations for plate finite elements
 2.4 Mathematical model of structural elements collapse
 2.5 Calculation of dynamic loading parameters in structural elements
Chapter 3 – Evaluation of the accuracy of mathematical modeling of the aircraft structure, payload and other items of mass
 3.1 Evaluation of the covered range of vibration frequencies
 3.2 Errors of finite element discretization of the structure
 3.3 Errors of numerical integration of dynamic equilibrium equations
 3.4 Rounding errors
 3.5 Calculation of dynamic characteristics of the aircraft structure, payload and other items of mass and comparison with test results
**Chapter 4 – Study of dynamic loading of items of mass during an aircraft emergency landing**
 4.1 Dependence of dynamic loading of items of mass on the landing surface properties
 4.2 Influence of aircraft movement parameters
 4.3 Effect of variation in the load bearing capacity of collapsing structural elements
 4.4 Determination of requirements for the attachments of items of various mass
 4.5 Evaluation of the probabilistic safety factor and establishment of the analysis cases for payload and other items of mass during an emergency landing
 4.6 The technology of application of the developed method in the design of payload structures
Conclusion
Bibliography

The developed method was not limited only to numerical analysis. It also demonstrated an engineering approach to the research of such an emergency situation which determines the design requirements, and it covered the development of practical recommendations for the design of aircraft and re-entry aerospace vehicles.
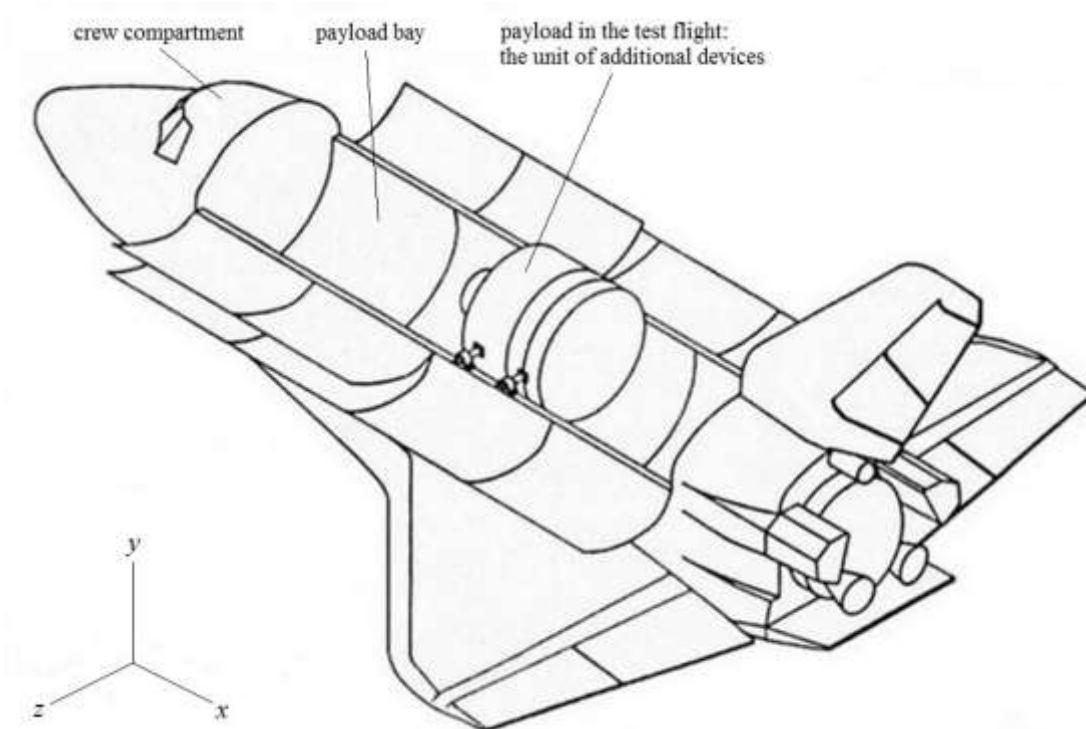
Original object of the research: the *Buran* aerospace ship

The description of this research and some other applications of the method can be found in the following publications (in Russian):

Lyakhovenko IA, Shenk YV, Spirochkin YK (1989) K voprosu o vozmozhnosti chislennogo modelorovaniya avariinoi posadki vertolyota. Nauchno-tekhnicheskii otchet NTO 03-5942 (On the possibility of numerical simulation of a helicopter emergency landing. Scientific and technical report NTO 03-5942). TsAGI, Zhukovsky, Moscow region

Spirochkin YK, Shenk YV (1990) Chislennoe modelirovanie avariinoi posadki vertoleta (Numerical simulation of a helicopter emergency landing). Problemy udara, razrusheniya i tekhnologii (Problems of impact, destruction and technology) 10(4):62-63 (Publishing house VNITsUR-Resurs, Riga)

Spirochkin YK (1993) Komp'yuternoe modelirovanie dinamiki konstruktsii pri avariyakh (Computer simulation of structural dynamics in accidents). Matematicheskoe modelirovanie (Mathematical models and computer simulations) 5(6):85-103. http://www.mathnet.ru/php/archive.phtml?wshow=paper&jrnid=mm&paperid=1984&option_lang=rus

Spirochkin YK (2020) Chelovecheskii faktor i proektirovanie (Human factors and design). Right Print, Saint Petersburg.

Further development of this method led to the creation of a methodology of wider application: FEM-based analysis of nonlinear statics and dynamics of structures.

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