Hardware-In-the-Loop Modeling system of flight control of the spacecraft "Luna-Glob" at the stage of the automatic landing on the Moon

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Abstract

The Russian space program lunar exploration involves automatic soft landing on the moon surface of the spacecraft (SC) "Luna-Glob". On-board control system of motion SC is created to implement this task. Integrated onboard computer system is processed measurements of two sets of inertial units, velocity and range Doppler devices. The output parameters of computer system are using for control of SC jet engines: correction and brake, two engines soft landing, four engines correction and stabilization and eight engines stabilization. The HILM system of flight control enabled to begin debug stage of the automatic landing software prior to the creation and assembly of complete sets of equipment SC "Luna-Glob".

Introduction

According to Russian Lunar space program Luna-Glob spacecraft should perform automatic soft landing on Moon surface. Onboard propulsion control software (OMCS) is developed for this purpose. Onboard propulsion control software should function as a part of integrated onboard computer (BIVK) in real-time mode. BIVK performs trajectory measurements processing and then generates commands for engine control system. Development and debugging of complex algorithms for onboard devices control is needed to perform onboard software verification. Usually this problem is handled after spacecraft had been constructed and tested. This research suggests parallel software verification and onboard hardware development.

1 Structure of propulsion control system

Propulsion control system is on of onboard control complexs (OCC) subsystems. Where:

1 - Electronic unit of drive control,
2 - Pyrotechnics explosion and automatics unit,
3 - Onboard Radio Complex.,
4 - Control Assembly,
5 - Antenna attitude control unit (operates after landing),

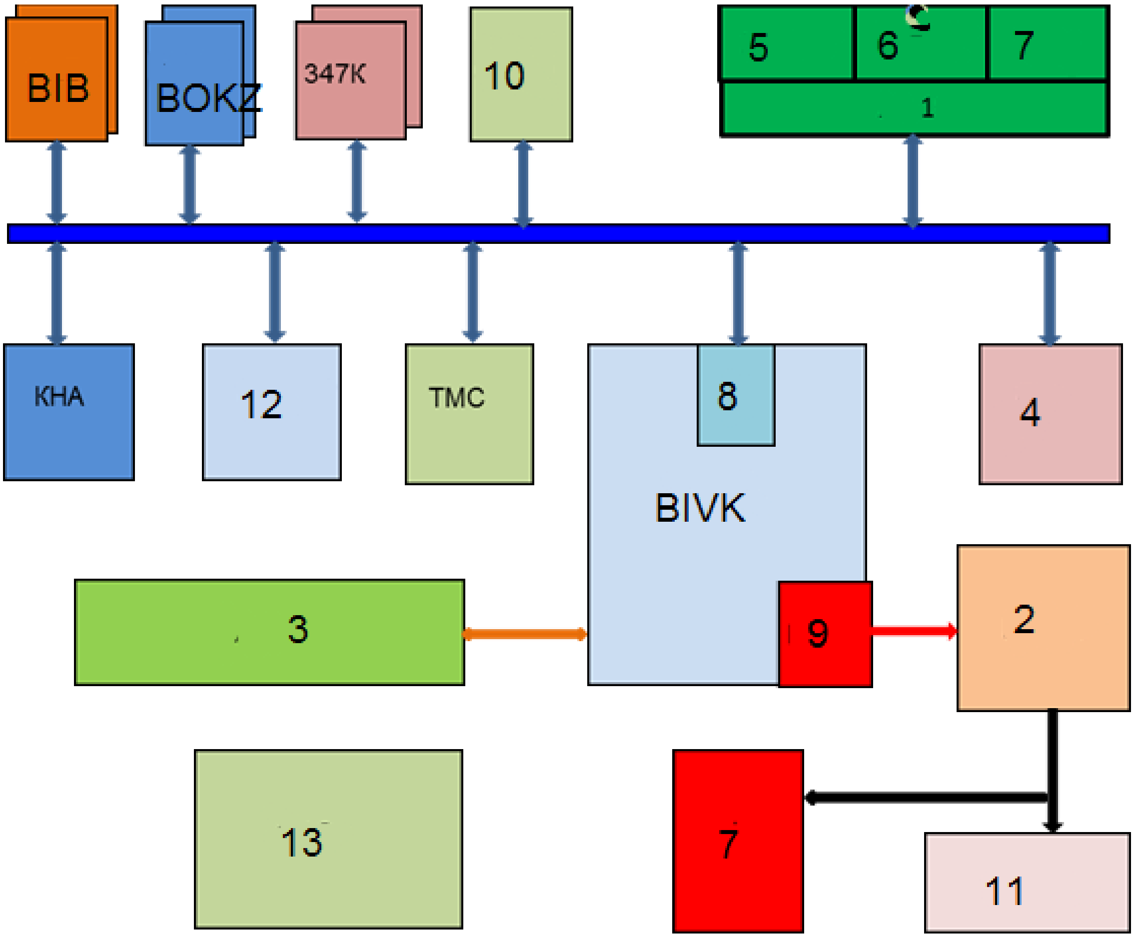

Figure 1: Luna-Glob spacecraft onboard systems scheme

6 - Correcting and braking engine thrust control unit,
7 - Jet engines,
8 - Controller,
9 - Relay command matrix,
10 - Remote terminal,
11 - Thermal regimes maintenance facilities,
12 - The TV shooting,
13 - Power supply system,

Spacecraft propulsion control system includes:
- Integrated onboard computer (incorporating two subsets) includes,
- Measuring equipment:
+ Two subsets of solar sensors;
+ Two subsets of unit positioning BOKZ stars;
+ Two subsets of strapdown inertial unit BIB;
+ Doppler velocity and distance meter DISD;
- BIVK software performing measuring tools information filtering and processing, calculation of spacecrafts orientation in inertial space and various reference frames,

calculation of algorithm controlling parameters, elaboration of controlling criterions or commands;
- Executing tools:
+ 1 correction and engine brake (KTD);
+ 8 stabilizing engines;
+ 4 correcting and stabilizing engines ;
+ 2 soft landing engines;
- Surface contact detectors mounted on 4 landing legs.
Information from measuring tools goes to IOC via MIL-STP-1553 multiplex data bus system where IOC is bus controller and all measuring tools are remote terminals. All controlling criterions and commands made in IOC go via MIL-STP to Control Assembly which forms real-time commands for electric automatic units performing direct control of drive and electric pneumatic valves of engine unit. Spacecraft onboard systems block scheme is depicted in Fig 1.

To provide propulsion control systems functioning onboard computer has to work within 50 s time cycle. In one cycle onboard computer must receive information from measuring tools, perform its filtering and processing, complete calculations for controlling algorithms, form controlling criterions and commands and send it to Control Assembly [1].

2 Landing propulsion control mode

Landing session moves spacecraft from Lunar orbit to its surface. The session includes preparatory operations and some specific parts of propulsion control. That is why landing session includes three sequential stages: 3-axis stabilization, main braking mode and precise braking mode. Landing scheme is depicted on Fig. 2.

Expected landing sites are located in the Southern lunar hemisphere in Boguslavskys crater. Several conditions should be met at the moment when landing legs touch lunar surface:
- Vertical speed must be in the range of 1 ... 3 m/s,
- Horizontal velocity should not exceed 1 m/s,
- Angle between spacecraft OX axis and gravitational normal vector should not overcome 7,
- The direction of the spacecraft center to the earth should be located near the plane of the spacecraft XY plane.

Propulsion control in this session is performed with the help of onboard computer BIVK (two subsets), two astronavigation instruments BOKZ (on preparation stage), two subsets of strapdown attitude reference system (BIB) and Doppler velocity and distance meter during the terminal part. Spacecraft orientation at every part of landing session is defined by controlling algorithms with the help of information obtained from measuring tools [2].

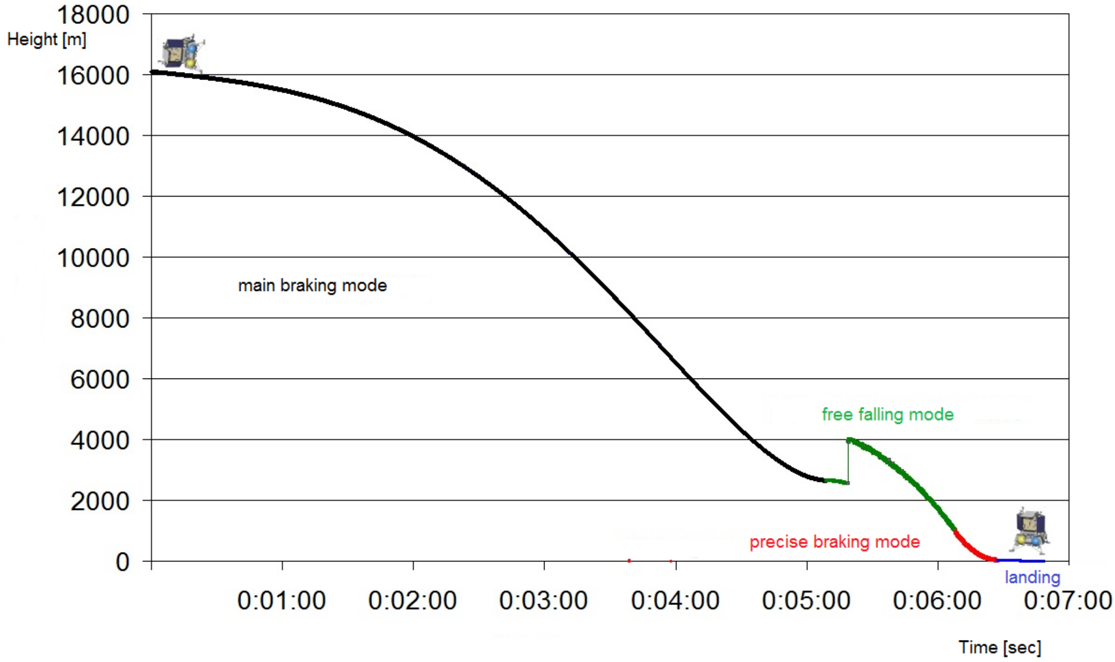

Figure 2: Landiing scheme

3 Experimental testing of software and hardware models

Planning, organization and realization of every test at every stage of spacecraft Luna-Glob units experimental testing should take in account peculiarity of every single test in order to obtain maximum volume of information to comply with requirements specification. A hardware and software modelling stand has been built at Keldysh Institute of Applied Mathematics in order to meet this objective.

Stand structure depicted in fig. 3 includes hardware model of general MIL-STP-1553 data bus, general Ethernet bus and two technological RS232 channels. All engineering and simulation models are plugged to MIL-STP-1553 bus. Usage of spacecraft units engineering models is limited due to limitations of their usage on Earth surface instead of open space. That is why some units engineering models are substituted by software simulation models.

Every software simulation model is a single PC with software simulating results that should be produced by units engineering model. Information traffic between engineering models and software simulation models goes via MIL-STP-1553 data bus in real-time mode. General Ethernet bus and RS232 channels are used to load onboard software and for information transfer in order to synchronize calculation processes.

Stand depicted in fig. 5 is controlled by a separate PC working as a server. Modelling results visualization is performed on the other PC it creates 3D graphics depicting landing process in real-time mode (see fig. 6).

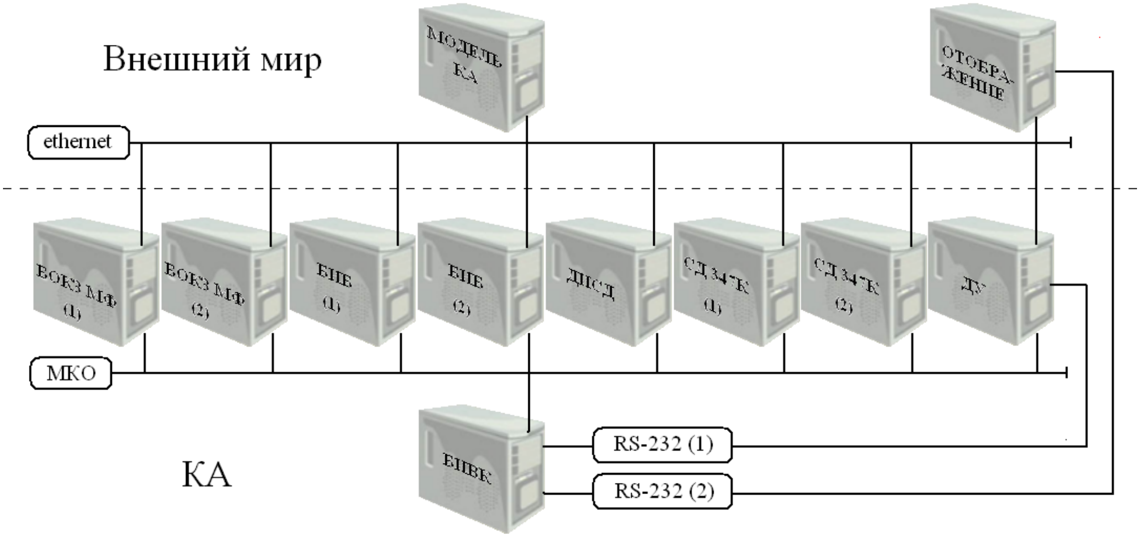

Figure 3: Testing stand structure

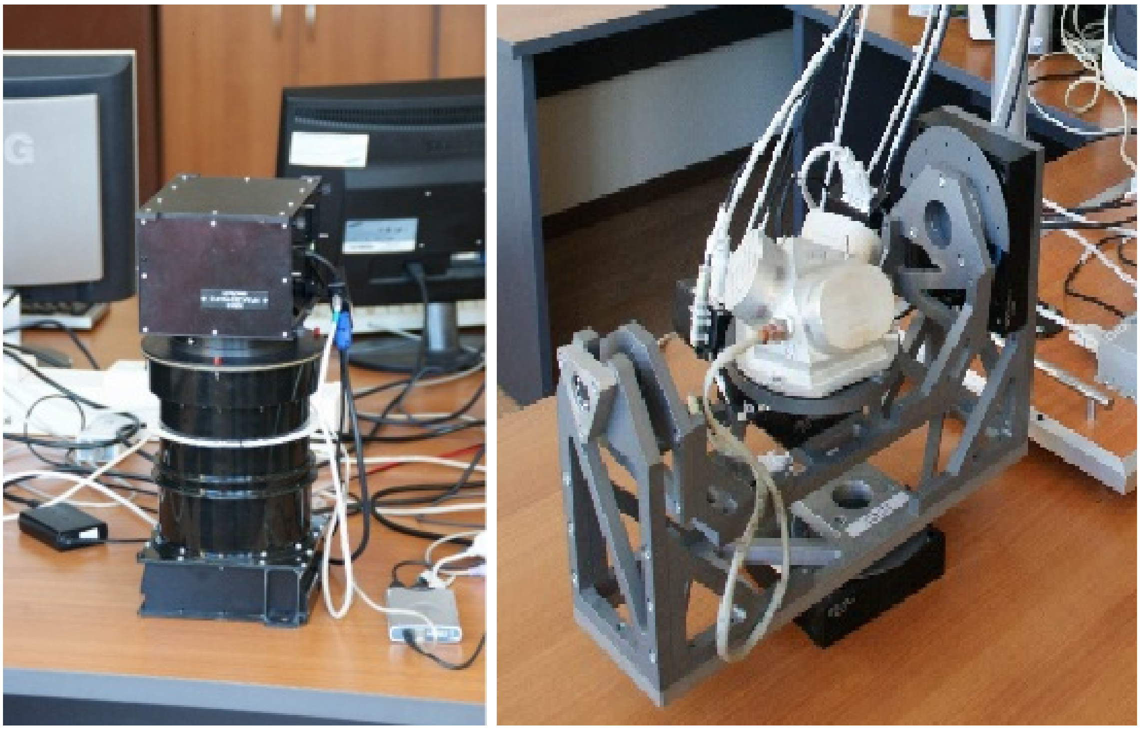

Figure 4: Engineering models of BOKZ astronavigation instrument and strapdown attitude reference system (BIB).

Measuring tools mounting and orientation errors as well as functioning errors within requirements specifications for each tool have been variated during modelling process [3].

Figure 5: General view of the testing stand

Conclusion

Hardware and software modelling allowed to perform propulsion control system software debugging before building whole Luna-Glob spacecraft which significantly shortens onboard software testing period. Hardware and software modelling stand developed in Keldysh Institute of Applied Mathematics has been used for assembled onboard software debugging in real-time mode with concurrent usage of spacecraft units engineering models and their software simulation models.

References

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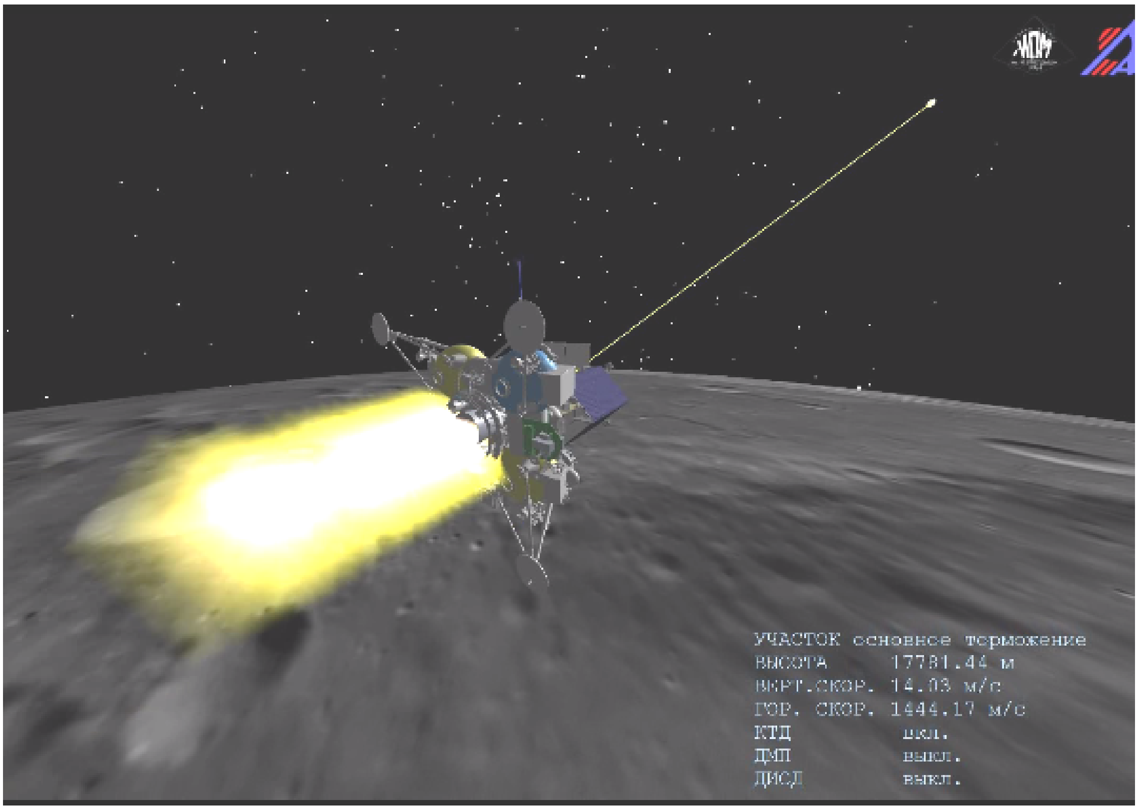

Figure 6: 3D visualization of Lunar landing session modelled by hardware and software modelling stand.

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