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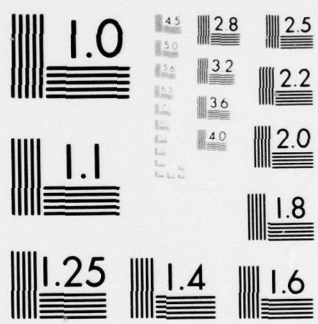

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SIMULATION AND SIMULATORS IN AVIATION SPACE
FLIGHT SIMULATORS

by

Jiri Holusa

FOREIGN TECHNOLOGY DIVISION

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SIMULATION AND SIMULATORS IN AVIATION SPACE FLIGHT SIMULATORS

Jiri Holusa

As a conclusion of the part dealing wih aviation simulators one should also remember to mention the space flight simulators. Partly because space travel is closely related with aeronautics but mainly because the space flight simulators represent todays highest point in simulation technology in general. In civil or military aeronautics there is always a certain limit which sometimes is utilitarian but mainly it is set by economic considerations. The aim is to train pilots or entire crews under training conditions on the ground and then it is more practical to carry out flight exercises. Space flight simulators represent an example of the so called total simulation which allows to recreate on a ground device the actual space flight conditions to such a degree that the crew will be able to work within the real space conditions with complete reliability. This is accomplished of course at the expense of great complexity of such simulators and of their ancillary installations which all require great economic investments and operational costs.

Simulators of various types of spacecraft are used by the two space powers, the Soviet Union and the United States. These simulators serve not only crew training purposes but also to check outworking and operational conditions of space ships. Their importance as well as the reliability of the simulation is demonstrated by the fact that during a real flight, of the Apollo or Soyuz programs, the substitute crew carried out a simultaneous simulator flight and in cases of any unusual conditions the substitute crew attempted to control any particular problems wirst and only then the real crew would receive their procedural instructions.

American space centers used simulators for all modifications in manned spacecraft of the Mercury and Gemini programs. Already in 1965, at the start of the program which send man onto the surface of the moon, it was ordered to build a simulator of the command module of the Apollo space ship (CMS - Command Module Simulators). One of them was installed at the manned space flight control center in Houston, Texas, further two were later put in the Kennedy Space Center in Florida. Their construction was completed in 1968. These simulators are the largest and most complex installations of such kind ever built anywhere. Each is about 10 meters tall and weigh about 40 tons. They were introduced to completely and efficiently train Apollo spacecraft crews for all space flight phases. In order to achieve fully all the training requirements all the conditions of a real flight had to be faithfully reproduced inside the cabin as well as around it. The simulator for the Apollo command module reproduced all flight phases, starting by pre-ignition preparation including the so-called count down time, ignition of the first and second stage rocket engines, their separation, guidance into the earth orbit, transfer into the moon orbit, communication of the command module with the instrumental section and their connection with the lunar module, trayectory correction towards the moon, transfer to the lunar orbit and up to the separation of the lunar module. During the return flight all the phases were also simulated from the docking of the lunar module in the lunar orbit, the flight back to earth including atmosphere re-entry and landing.

The simulator cabin was kept motionless. The sense of motion was not simulated directly by physical means but only through visual devices. The reality of the flight was implemented by all pertinent sound effects such as the booster rocket engine noise, noise of control engines, noise of pyrotechnical mechanisms etc. Smoke could be injected into the cabin to simulate the burning of electrical wire insulation to cover cases of fires or chemical reactions that may occur onboard. To complete the scene, life conditions were also imitated such as oxygen supply and air regeneration, water supply regeneration, storage of poisonous materials in the refrigerator, food preparation procedures and finally the elimination method of excretions. To mimic the earth atmosphere re-entry the space suits of theastronauts were heated.

The command modules were outfitted ad looked differently depending on the individual Apollo program flights. The command module of each flight had its own characteristics which had to be included in their simulation. Because of this the actual simulator cabin was set on rails so that, when needed, it could be quickly and easily replaced with another version.

Of particular significance was the visual orientation simulation system which had to imitate faithfully objets at a distance of not quite 2 meters away (the lunar module) as well as objects at distances of many light years (stars up to the 6th. magnitude order). Images of the sun, earth, moon, lunar module clouds etc had to change same as during a real flight. The image was created in all four windows of the spacecraft and in further six versions images from telescopes and sextants were simulated. A realistic visualization was assured first of all for the docking maneuver with the lunar module by means of a color television system with a high image resolution ability. During the lunar module docking the lunar module image was televised by a complex optical system using a small scale model At a distance of 1.8 to 180 m the image dimensions were changed proportionally to the distance. From 180 m to 2400 m the lunar module's image appeared as an object of constant dimensions and beyond 2400 m it appeared just as an illuminated point.

The mathematical model which described the flight and the spacecraft functions, including the systems of the Saturn booster, was solved in a real time-frame with a repeat frequency of up to 20x per second by a set of four digital computers (Honeywell) which cooperated in parallel as one unit which was capable to perform up to one million operations per second. The data transfer speed at the input and output terminals reached up to one million of turns per second through one transducer. The computer also created telemetric data in a real way so that their simulated transmission could be received by the ground command center.

The functioning of the simulator was governed from the control and steering section of the simulator. From there a three member service group managed the individual simulator systems, monitored all the actions of the crew, started the initial training conditions and simulation of all kinds of problems, recorded the flight parameters and the crew reactions. The instrument panels of this section duplicated all indicators and equipment of the spacecraft as well as indicators for the position of all switches and controls of the spacecraft cabin. The communication with the crew was assured by a television system which monitored the crew during the entire flight simulation. The flight of the spacecraft could actually be "frozen" instantly for any length of time with respect to all parameters. It was also possible to store any flight segment in the magnetic tape memory bank of the computer for later re-runs.

The simulators cooperated within an integrated regime directly with the ground space flight command center in Houston. This allowed not only to maximize the simulation of real conditions of future space flights but also made possible a simultaneous training of the spacecraft crew and the ground control staff at the center. To simulate the function of the ground assurance media, such as radio--location and tracking stations etc. the control center was linked with a further complex of computers which assured that simulation. During the simulation of communications between the spacecraft and the ground control center the signal delay corresponding to the distance between the spacecraft and the earth was also simulated.

For the training of the actual moon landing other moon lander simulators were used. One was in Houston and the other in Florida. The simulations could be used independently or in conjunction with the command module and the ground control center. As in the command module the moon lander had simulations of all its functions: controls, systems and equipment. The view from its windows were simulated by television images taken from an exact model of the moonscape at the projected landing site.

In the manned moonlanding program other two training devices were used which do not belong among the electronic simulators considered here so far but it is useful to mention them as well.

One of them was a free-flying device maintained aloft by a lifting jet engine with a directional draft vector which could simulate the different flight stages of the lunar module within the lunar gravitation conditions. The control organs ancillary equipment and all their functions corresponded with the lunar module. Five such trainers were built by Bell Aerospace. In order to rescue the pilot in case of engine failure this trainer had an ejection seat provided with a rocket engine. During one of the training flights, on May 6, 1968, due to control problems the trainer maneuvered into an uncontrollable position angle and its pilot, Neil Armstrong (who later became the first man to step on the moon) was saved by the ejecting seat.

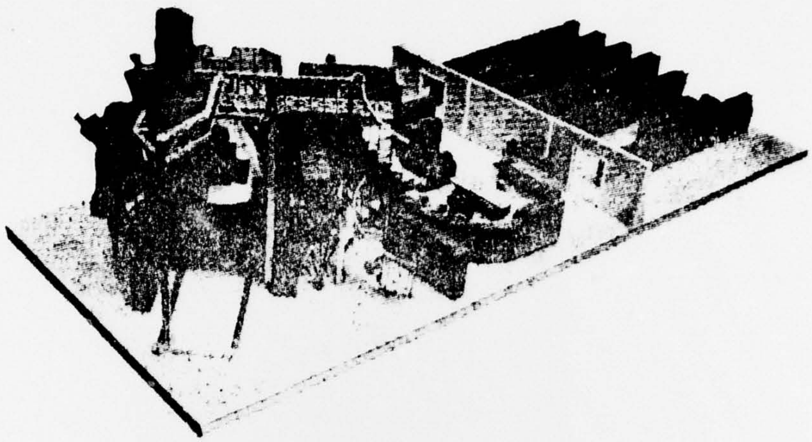
The other trainer was built for research and development tasks related to its landing functions on the moon. It was located at the Langley Research Center. This trainer consisted in a tall support structure with a moving hanging part to which a mock-up of the moon--lander was attached. The suspending arrangement allowed the mock-up to move 110 meters lengthwise, 15 meters transversally and 55 meters vertically. This suspension allowed any rotation of the model around all its three axis and the models weight was 5/6 of the real weight to simulate the conditions of the lunar gravitational field. To keep the mock-up aloft and for steering purposes it had reaction engines fueled by hydrogen peroxide. The model could achieve a speed of up to 27 km/h.

In 1971 in Houston a simulator of the Skylab satellite was introduced. It assured a realistic simulation of all its systems and equipment including of all experiments planned onboard. The simulator was controlled by a IBM 360 Model 65 computer. In 1972 NASA finalized its bids order for the construction of a simulator for a rocket-craft (Space Shuttle).

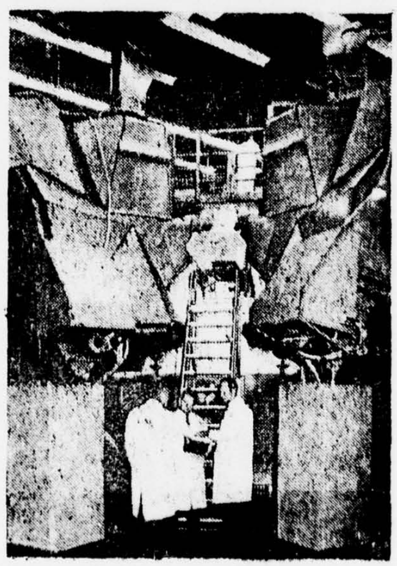
As in the American space centers, space ship simulators are widely used at the Soviet Cosmonauts training center at "Star City". During the joint flight Soyuz-Apollo preparations the Soviet cosmonauts trained jointly with their American couterparts on the complex Soyuz space ship simulators. The Soviet crews also trained at the American Center. According to their comments the training with these simulators assured a very thorough technical preparation of both crews.

The complex simulator of the Soyuz space ship is substantially similar to the Apollo command module simulator. Fundamentally it isan exact reproduction of the real space ship for a two-membered crew. For docking operations exercises of the spaceship with the satellite station Salyut the docking simulator Volga is used. It consists in an exact copy of the Soyuz spacecraft adjoining an exact copy of the Salyut station which aim it its opponents diminished models up to a distance of 15 meters. The aimed-at object is observed by the cosmonauts through a periscope or by means of a television image.

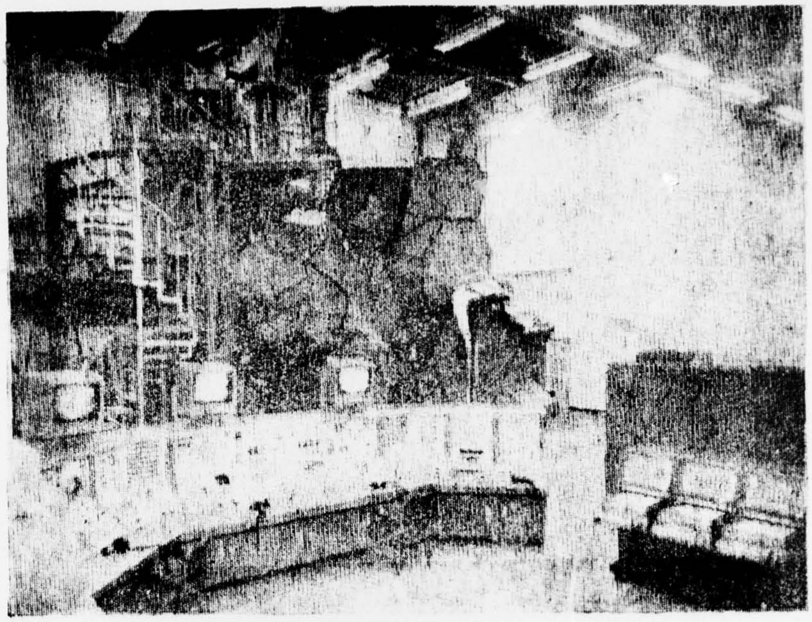
Next time: Czechoslovak flight trainers and simulators



Model of Apollo command module simulator

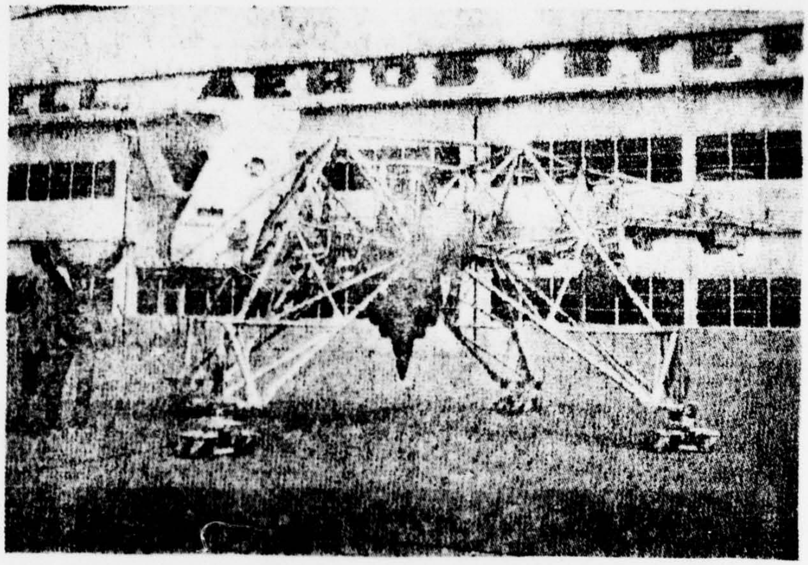


Cabin of the Apollo command module silulator and a group of developers.

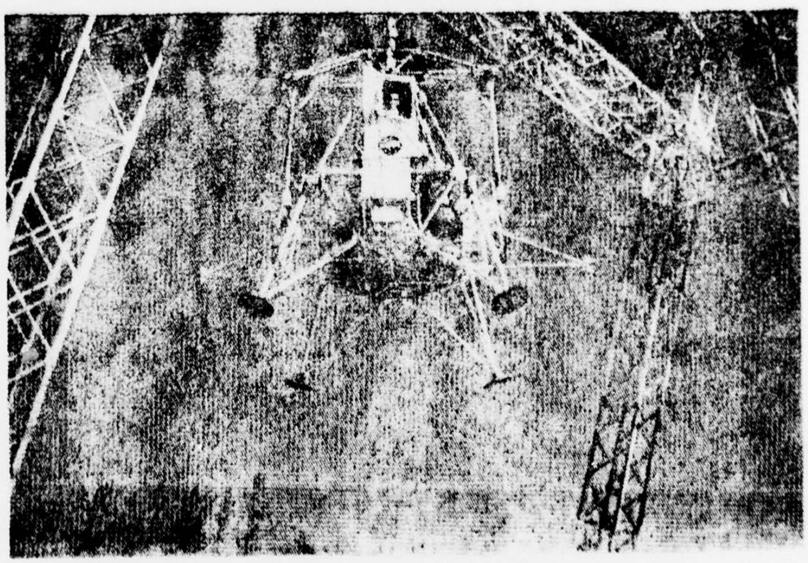


Simulator complex of the Apollo command module. In foreground - control and steering section of the simulator

Cosmonauts V.A. Dzhanibekov and B.D. Andreyev in front of a Soyuz spaceship simulator.



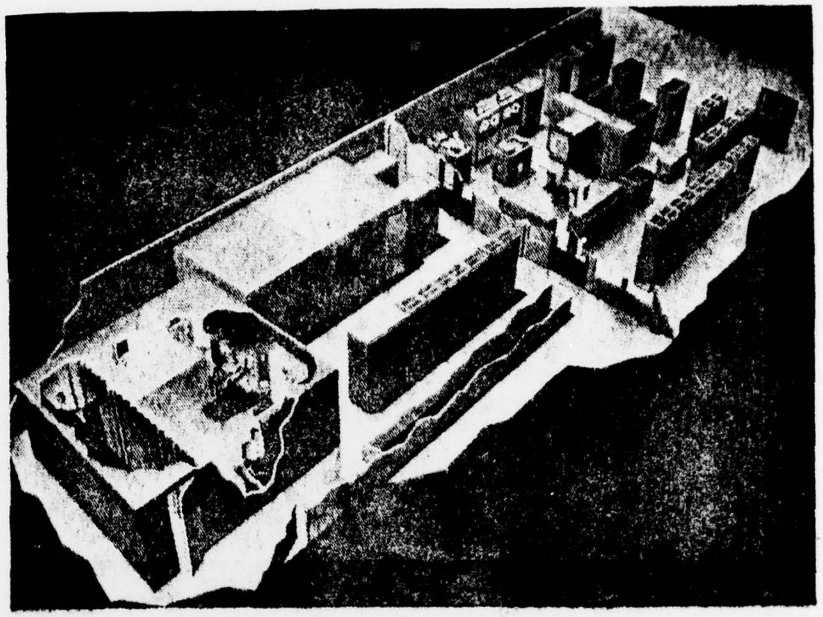
Trainer for moonlanding exercises - Bell Aerosystems.



Developmental simulator for moonlanding - NASA

Reserve crew of the joint Soyuz - Apollo flight. A.V. Filipchenko and N.N. Rukavishnikov at the control panel of the Soyuz simulator.

Another reserve crew for the joint Soyuz - Apollo flight. V.A Dzhanibekov and B.D. Andreyev during training. In background - - simulator of the spaceship Soyuz.



Simulator complex Skylab

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