SPACE SCIENCE EDUCATION WITH MATHEMATICA: INTERACTIVE DESIGN MODULAR SPACE STATION STRUCTURES WITH COMPUTER ALGEBRA: PRINCIPLES, FUNCTIONAL UNITS, MOTIONS, EXAMPLES.

Kabai, S.[1], Miyazaki, K.[2], Bérczi, Sz.[3] [1]UNICONSTANT, H-4150 Püspökladány, Honvéd u. 3. Hungary, [2]Kyoto University, Faculty of Science, Graduate School of Human and Environmental Studies, Sakyo-ku, Kyoto 606-8501, Japan [3]Eötvös University, Faculty of Science, Dept. G. Physics, Cosmic Materials Space Research Group, H-1117 Budapest, Pázmány Péter sétány. 1/a. Hungary. (unico@mail.matav.hu)

Abstract: In order to design a space station with modular structure first we formulated basic principles: central **core:** the house, with rigid construction, surrounded by a skeletal frame of "**front-garden**", a belt built for emplacement of larger space objects, and a third shadowing and **antenna region**. Core is a closed structure, here with icosahedral symmetry. Front-garden is a loose, skeletal, permeable and "transparent" belt surrounding the inner non-transparent body of the "house". Antenna (and shadowing plates) outer region define forbidden directions for electronically noisy activities. With the Modular Space Station Planning we initiated a new field of use of Mathematica programs making visual models of designed forms, making possible docking (Fig. 1),

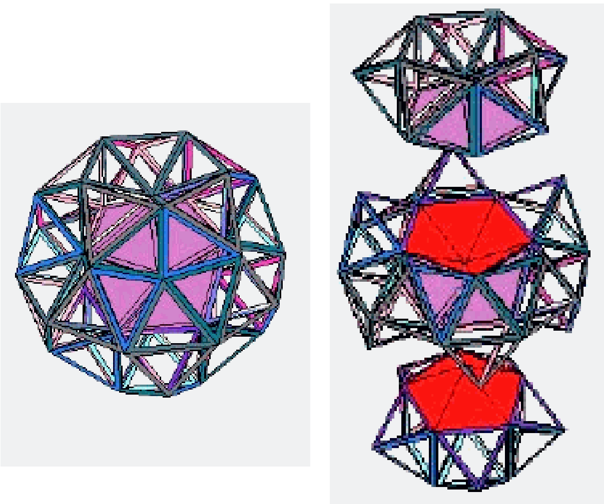

Fig. 1. Construction from subunits.

moving around constructed structures. We study some final designs, some subsystems and discuss the their benefits.

Introduction: In XXI. century mankind will build new instruments, new working and living complex platforms and place them into orbit around Earth. Instruments and larger laboratories have been built in the form of space structure assemblages for accommodation of people working on the station. Both MIR and ISS are the first such type platforms in the space. In the far future space architecture develop larger complex systems of which planning is an interesting way to space science education.

Design of these large complexes we began first by formulating and selecting the basic principles for construction, structure and use. According to recent common knowledge space station is a large, integrated unit of modular blocks built together. We focused on the geometry and regions, the use of modular building together, the approaches to the deeper belts of the Space Station. Our structures consist of an object with global central symmetry in the 3D space. We use the expressions for the central symmetric structures, like in Planetary science. There a planet has three main belts: a core, a mantle and a crust. At the same time we use expressions for the house or other buildings we are accustomed to. Therefore our words will mix expressions from planetary science and architectural engineering.

Three belts of Space Station Units: From center to edge 3 regions form belts: core, "front-garden" and antenna and insulating shield region. In our structure with central symmetry the belts represent different functions of activities. The central core is the House. The place of living in a closed system. There are the living blocks, the main working laboratories and storing system, life support systems, energy and communication systems. There is a place for connections to the next belt: front-garden. In the front-garden we find the place of those activities which need some relation with the free space. Front garden connects closed House with the neighborhood. Doors and docking units are here, but from the design point of view the most

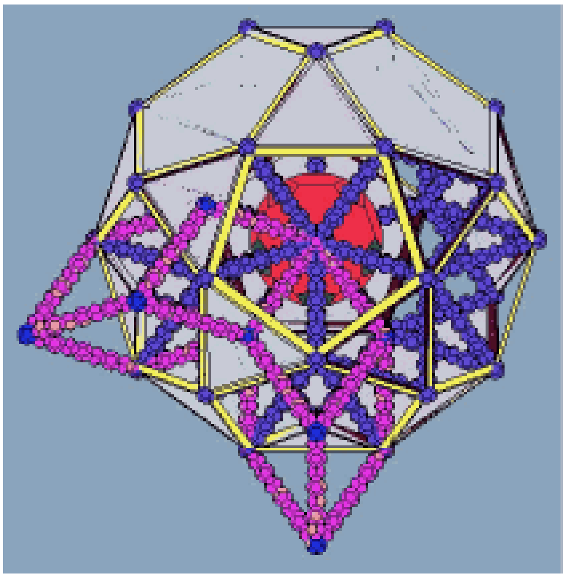

Fig. 2.

important role is the skeletal transparent framework in this belt. This region is an outer loose shell compared to core house, because movements and transportation, docking and near space station works can be done or organized here.

Core and front-garden together determine the main shape of the Space Station. The antenna and shielding region add forbidden zones to the activities. This loosest outer shell, however, still serves as place for outer orientation (to Sun, toward objects in activity) and shows always main directions, too. So this outer belt has spatial function in the three belt organized Space Station [1,2].

Recognition of the main double "layered" basic inner form of a Space Station and the third layer of outer antenna+shield region (Fig. 2.) connects our studies to those layered structures which are frequently used for 4D regular solids, when they are represented in a central, embedded construction (see for example Kajikawa, 1992 [3]).

The constructions: with icosahedral and pentagon-dodecahedral forms: Outer view of the most important parts of the Space Station designs. Using Mathematica the graphic design of the Space Station constructions are shown on Fig. 1-4. Skeletal structure of the transparent antenna region, front-garden shell structure, + surface of the inner core.) Interactive works with the structure: the orbital motion transparency and permeability from the inner core building through the front garden is important. Heat shielding of the core house of central position makes necessary to design moving surfaces along the outer surface of the front-garden belt, too. This criteria appears partly on the designs.

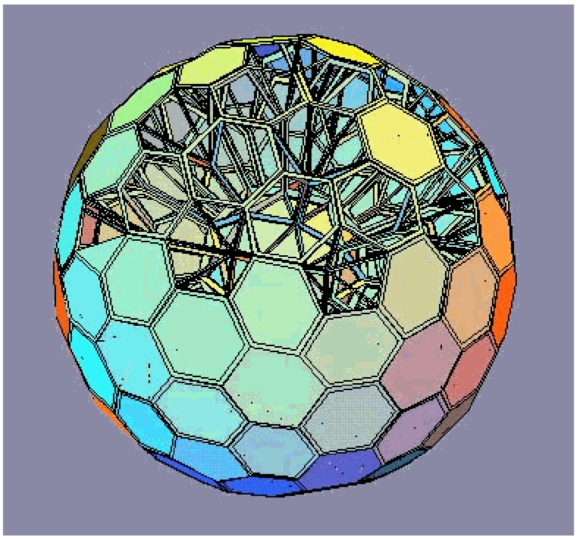

Fig. 3.

The reasons of the preferred fivefold symmetry structures: Why we prefer icosahedral symmetry in Space Station design? Observing the results of the last 20 years [4-7] in structural sciences the role of icosahedral and pentagon-dodecahedral structures increased. We refer to two main reasons why we plan Space Stations with global icosahedral symmetry [2].

Fullerene-like structures are known, they have (5,6,6) Steiner symbol (one 5-gon and two 6-gons meet). Shell structures have been built in great number in the modern architecture. In material science X-ray metallic structure of metal-glass clusters turned out to be icosahedral: during clustering the first 3-4 layers (metal cluster embryo) begins to grow. (We also find icosahedral form in the world of viruses, and fullerene science found also the icosahedral symmetry for large closed aromatic hydrocarbon molecules. Not only fullerenes but nanotubes also belong to this field of chemistry.

From these short examples we can see that the local environment prefers fivefold symmetry in many hierarchy levels in nature [8,9].) In space constructions it implies that empty spaces remain between the tiling modular units if they have fivefold symmetry. Therefore the spongy, vesicular or permeable spaces can be best designed if the modular units are ones with fivefold symmetry.

A working platform sub-unit with a grid surface: Finally we show a sub-unit in the Space Station. It is always important to make fix points where the astronauts can relax and may feel some stable point for orientation. We could see in the Space Center Houston Skylab exhibition that in the Skylab Space Station levels were made from hexagonal patterns and that the spacesuit shoes were formed with such type of bottom to be fixed sometimes to the ground level. We formed such connecting sub-units for our Space Stations. This sub-unit can be placed at turning points in the front-garden. This structure is also permeable, and the place of pentagons are empty to see over them. This fullerene relaxing point is also an example to the use of fivefold units in the vicinity of Space Stations.

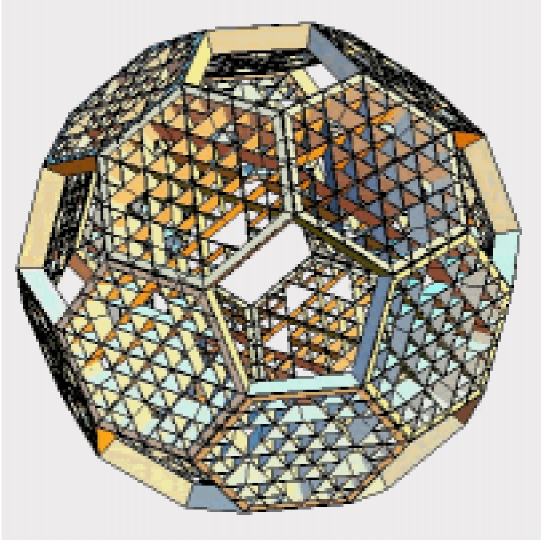

Fig. 4. Skylab type grids on a local connecting unit.

Summary: We worked out a course with initiative to design Space Stations and move in and around it. After characterizing basic principles, we defined three main regions in a centrally structured Space Station: inner core (the house, closed structure, planned with icosahedral symmetry) a second belt: front-garden, (permeable, transparent, loose, skeletal framework surrounding the non-transparent core) and outermost antenna + shield region (defining forbidden directions for electronically noisy activities + actual shielding directions). All the designs were shown by Mathematica programs and the motions were seen by vrml type programs. Our new educational field of geometry and space research is not only for making visual models of the designed (fivefold) structures but for suggesting that it is a joyful practical course for students studying design by computer and using computer graphics in planning dreams far away from our everyday flat space, but not so far in future.

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