Committee: Space Transportation, Mining, Industry

Chairman: **Werner Grandl**, architect & civil engineer

Biography: born 1957 in Vienna, Austria
1984 Technical University Vienna, degree in architecture
1985 military service, Austrian Air Force
1986-1993 working in some engineering offices
since 1994 freelancing architect and consulting engineer
since 1987 various studies on space stations, space colonies, lunar base design and asteroid resource utilization

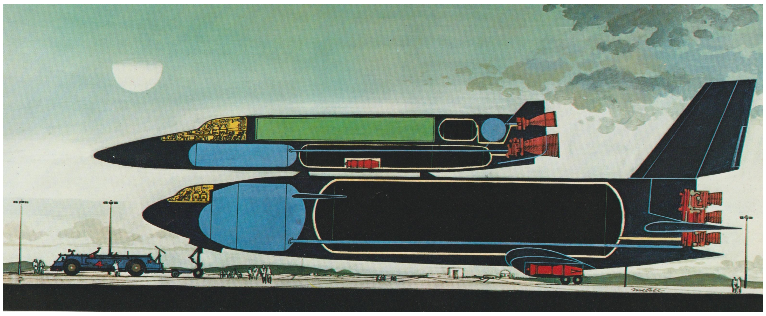
The Space Transportation, Mining, Industry Committee includes the study and further promotion of the key items of the geo-lunar space region industrialization: 100% reusable, low cost, safe and ergonomic space launch systems, production of fuel in space, moon and asteroid mining, reusing orbital debris, and industrial development in space. Our goal is to promote civilian space travel and in the long run civilian life in space, in the Earth-Moon system and its Lagrange libration points.

1. Space Transportation from Earth to Low Earth Orbit (approx. 450 km altitude):

New launch vehicles like *SpaceX Falcon 9* or *Falcon Heavy* can carry payloads between 22 and 54 tons to Low Earth Orbit (LEO). Also the European *Ariane 5ES* or the Russian *Proton M* can launch about 20 tons to LEO. The SpaceX Falcon rockets now have reusable first stages and may reduce payload costs to approx. $ 2700 per kg. These rockets can be used primarily for cargo-transport to LEO.

1.1.The original US space shuttle concept from 1970:

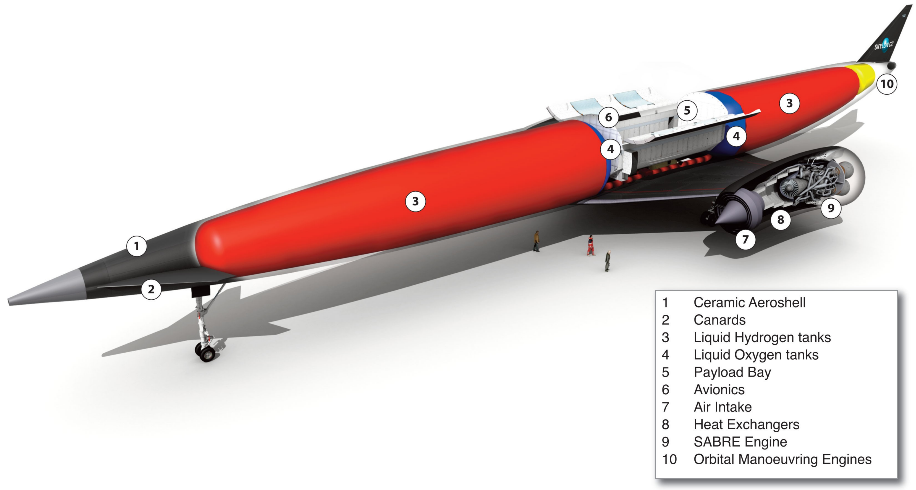
The original space shuttle concept of NASA was based on two coupled manned vehicles, the Orbiter and the Booster vehicle, both 100 % reusable. The coupled space vehicles would be launched vertically, and both could land horizontally. At an altitude of 80 km the Orbiter would fire its engines and separate from the Booster vehicle. Both spaceplanes were propelled by throttleable oxygen- hydrogen engines (with no CO2 emissions). The payload capacity of the Orbiter was about 11.3 tons for cargo-transport. A complementary pressurized cabin compartment for 12 passengers and two crewmen has also been proposed. The concept was a first step towards civilian passenger (space tourist) transportation.



Space shuttle concept with 2 manned vehicles (NASA 1970, credit Robert McCall)

1.2.HOTOL (Horizontal Take Off and Landing):

The SKYLON vehicle was designed by Reaction Engines Ltd., a British company, in recent years. The vehicle will take off and land horizontally on a heavily inforced runway. It is propulsed by SABRE engines (Synergistic Air Breathing Rocket Engines). After starting and accelerating in the air-breathing mode to an altitude of 25 kilometers, the engines transition to the rocket engine mode, using liquid oxygen stored on board. SKYLON´s fuselage and wing bearing structure is made from carbon fibre reinforced plastic, the propellant tankage for hydrogen and oxygen is built of aluminium. The external shell (the aeroshell) is made from a fibre reinforced ceramic.



Skylon cutaway: lenght 82 m, wingspan 25 m, unloaden mass 41 tons, fuel mass 220 tons (credit: Reaction Engines Ltd.)

SKYLON can carry a cargo payload of approx. 10.5 tons to 460 km LEO. Inside the cargo bay a cabin module for 30 passengers would be possible. SKYLON is supposed to reduce the cost of transport into LEO to approx. € 800 per kg.

2.Space Transportation between LEO, the Moon and the Langrange Points:

The design of fully reusable space transportation vehicles and the production of fuel in space will in the long run downsize transportation costs in cislunar space and be a key milestone towards future space settlement.

2.1.A shuttle service in cislunar space:

Once that space stations in Earth orbit, the Lagrange Points and on the Moon (or in lunar orbit) will be established, there will be shuttles for passenger transport and space tugs for cargo between these locations. For propulsion the fuel will be produced in space, either on the Moon or by processing Near Earth Asteroid material. Oxygen can be extracted from lunar material, hydrogen from frozen asteroids.

2.2.SpaceX Starship:

The SpaceX Starship design by Elon Musk is considered to carry a payload of 150 tons to LEO.

The entire configuration will be fully reusable. It can also be used for a journey to the Moon, landing on the lunar surface with a payload of approx. 20 tons and return to Earth without orbital refueling. On the Moon the payload is let down from top of the starship by an extendable elevator.

3. Deep space travel:

This committee focuses on transportation within the cislunar space. A journey of civilians to Mars and other planets and moons will need further research. Besides the Mars-Starship project of Elon Musk one can assume the development of future propulsion systems like the Bussard Fusion Engine. This hypothetical engine is considered to fuse Deuterium and Helium-3, producing Helium-4 plus protons and releasing 18.3 MeV of energy per reaction. For the reaction a specific energy of 3.5×10^{14} Joule/kg can be computed (Bussard 2002), i.e. orders-of-magnitude higher than for any existing propulsion system. Helium-3 is rare on Earth but abundant in lunar soil as a product of solar flares (see also 4.1.).

4. Mining the Moon and Near Earth Asteroids (NEAs):

4.1.Mining the Moon:

Many metals, such as iron, aluminium or titanium, can be extracted from lunar minerals (oxides), leaving oxygen as a by-product. Water is supposed to be found at the poles of the Moon. The processed material can be packed into boxes and catapulted into lunar orbit by an electromagnetic mass driver (magnetic levitation) due to the low mass and gravity of our Moon (O´Neill 1977). Helium-3, an isotope of helium, is rare on Earth but can be found in the regolith layers of the lunar surface. He3 can be used for potentially nuclear fusion, but also for low temperature physics, medical lung imaging or neutron detection. Approximately one million tons of He3 have been implanted by the solar wind during billions of years (Kuhlman et al. 2012). Although many operations on the Moon will be done by robotic devices and artificial intelligence, a manned lunar outpost will be necessary (Grandl 2012). According to Krafft Ehricke (see References) this lunar outpost could be the first step to lunar industrialization and human settlement on the Moon.

4.2.Mining Near Earth Asteroids (NEAs):

The number of known NEAs has increased continously during the last 30 years to approx. 18000 objects. Many of them are supposed to contain rare metals like platinum group elements or Rare-Earth elements, which may be extracted more easily from NEAs than from terrestrial soil, without environmental pollution or political and social problems. C-type (carbonaceous) asteroids contain oxygen, hydrogen and carbon. To exploit these asteroid resources efficiently, it will be useful to change the solar orbit of a NEA into an Earth orbit beyond the Moon or even to force it into a Lagrange Point of the Earth-Moon system. For this purpose we will need advanced propulsion systems like the Bussard Fusion Engine (Grandl, Bazso 2013). An Earth orbit of the NEA enables us to keep the rate of mining advance equal to the rate of cargo-shipping between the NEA and the industrial plants at the Lagrange points or in LEO.

5. Current Studies and Objectives:

The current ISS in orbit will probably be decommissioned until 2030. Besides the new Chinese orbital station we will develop a successor of ISS. For this reason we propose a rotating orbital station with simulated Gravity (see also SRI Space Habitats Committee).
This new orbital station shall also be used as a refuelling device for spaceships and space tugs.

Current engineering work and development plan:

- Designing an industrial plant layout at a Lagrange Libration Point
- Designing a „Space Tug“ for human and cargo transport in cislunar space
- Research for reusing space debris for space industry
- Workout of a time schedule until 2100
- Estimation of costs

Partnerships :

- Looking for partnerships with technical universities, ESA, space industries
- implementing space industrialization into the UN sustainable development goals

Further Reading:

Autino AV (2022) Selenopolis, the Krafft Ehricke view of Moon Industrialization and Settlement, Space Renaissance Art & Science Festival -Berlin 7-9 July 2022 https://www.youtube.com/watch?v=giQimsICFjE&t=6835s

Freeman M, Krafft Ehricke´s Moon: A Lush Oasis of Life.

NASA Astrophysics Data System (provider): A Vision of Lunar Settlement, Lunar and Planetary Institute.

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