EMC18 Abstracts

In alphabetical order

SCORPIUS PROTOTYPE

Théodore Besson[1]

SCORPIUS PROTOTYPE - TOWARDS A PROOF OF CONCEPT OF A CLOSED HABITAT ON-GROUND DEMONSTRATION INTEGRATING MAIN BLSS FUNCTIONS

Théodore Besson[1]

Key words: ground demonstration, terrestrial to Space technology transfer (spin-in), BLSS modules interfacing and integration, short to long term manned R&D campaign, preparation and financing of manned space missions, closed habitat specification definition.

First, the presentation will address the relevance of Earth-based applications of bioregenerative life support system (BLSS) for terrestrial sustainability. It will then introduce the challenges and ESTEE‘s approach for designing a terrestrial closed habitat demonstrator such as Scorpius Prototype (SP1), and the kind of research campaigns that can be implemented within a ground simulator. SP1 is an autonomous terrestrial solution integrating existing and emerging BLSS-related technologies. This prototype of a (semi-)closed system has been fully designed in 2017-2018 and its building is about to be started. This proof of concept is aimed to become a first step towards the on-ground development of a BLSS simulator with the highest possible level of material loop closure. Most space agencies develop a long-term roadmap for ground simulation of LSS with humans, especially as they are working on higher technology readiness levels compared to the ones of SP1. Nevertheless, one can consider that there is nowadays a clear need for an integrated closed habitat demonstrator such as SP1, in order to enhance the preparation and financing on Earth of manned space missions. Finally, the presentation will discuss the interest and benefits of establishing a standard on closed habitat specifications, in order to facilitate the synergies between Earth and space stakeholders working on sustainable, autonomous, and self-sufficient habitats.

[1] Managing Director at Earth Space Technical Ecosystem Enterprises (ESTEE); BLSS specialist; Oïkosmos project at Université of Lausanne (MELiSSA)

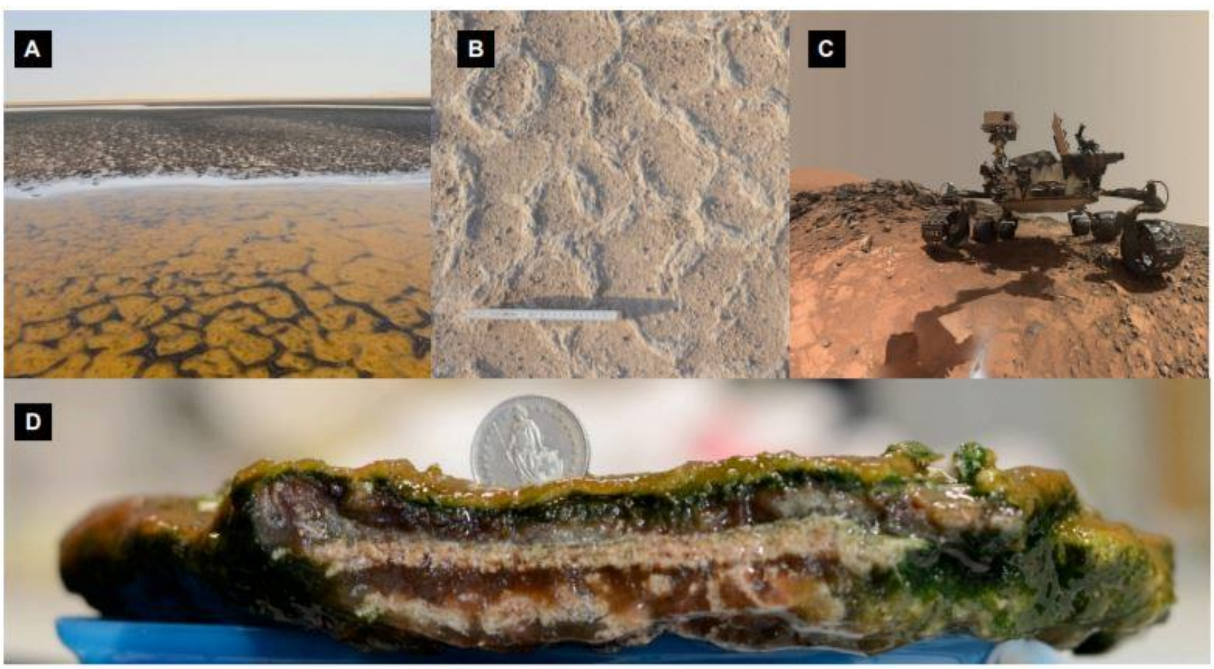
MORPHOLOGICAL BIOSIGNATURES ON MARS: WHAT TO EXPECT AND HOW TO PREPARE NOT TO MISS THEM

Tomaso R.R. Bontognali[1]

The presentation will focus on the strategies used during the current and forthcoming robotic missions to possibly find evidence for past life on Mars, with special emphasis on morphological biosignatures.

Key words: ExoMars mission, exobiology, biosignatures

Thanks to the new generation of rovers equipped with instruments capable of making "contact science", which includes acquiring high-resolution images of geological samples and performing sophisticated mineralogical and geochemical analysis, the search for life on Mars is in the middle of a particularly exciting phase. This contribution will focus on the general strategies that are used in the current and forthcoming robotic missions (MSL, ExoMars, Mars 2020) to look for signs of extraterrestrial life, with special emphasis on morphological biosignatures. To best prepare for the missions and to refine our ability to identify and correctly interpret putative morphological biosignatures, research is currently done on Earth in places referred to as Mars-analog sites, where conditions both in terms of geology and biology are similar to those we hypothesize may have existed billions of years ago on Mars. Examples of such research include microbe-mineral interactions occurring in the sabkhas of Qatar. In these extreme evaporitic environments, stromatolites and other microbially influenced sedimentary structures form thanks to the activity of primitive microbes, producing morphological biosignatures that are highly relevant for the field of exobiology.



(A) *The Khor Al Adaid sabkha in Qatar is studied as a Mars-analog site.* ***(B)*** *Outcrop showing morphological biosignatures consisting of fossil microbial mats* ***(C)*** *The NASA rover Curiosity (Image credits: NASA/JPLCaltech/ MSSS).* ***(D)*** *Microbial mat comprised of primitive microorganisms that induce the formation of a morphologically complex mineral structure. Except (C) all images were taken by Bontognali.*

[1] Research Scientist with PhD in Geobiology, CLUPI Science Validation Manager, ExoMars 2020, Space Exploration Institute, Neuchâtel, Switzerland

HUMANS ON MARS WILL HAVE TO LIVE ACCORDING TO BOTH MARTIAN & EARTH TIMES

Pierre Brisson[1]

The different lengths of day and year on Mars will impose the choice of specific references for the people who will live on this planet. However for a very long time no Martian will live a Martian-only life. The necessity for them to keep tight links with Mankind on Earth will also impose to share their time references.

Key words: dual-time, hidden days

The different lengths of day and year on Mars will impose the choice of specific time references for the people who will live on this planet. However for a very long time no Martians will live a Martian-only life. The necessity for them to keep tight links with Mankind on Earth and use Earth-made products will also impose to share their time references. The only realist solution is therefore to keep a dual-time reference system for the long-term (multiples of days, weeks, months, within a year), as well as the short term (divisions of the day).

For the short term, people can wear a watch with two screens, but they will keep the terrestrial time for their machines and interactions with Earth (no need for a small hand showing Martian seconds!).

Specifics of Martian Time will also have to be dealt with for the long-term reference system.

Seasons will have a special importance on account of the eccentricity of the orbit (which implies major differences between those of the Southern hemisphere versus those of the Northern hemisphere). They will have to be divided into months in order to allow an easy follow-up and the choice for these will be between 12 months with twice as many days as on Earth or 24 months with about the same number of days as on Earth (I personally opt for the first solution). I presume that the week will remain a seven day period as this is a custom coming from the night of human times and that there is no Martian reason to change it.

A choice will have to be made for the starting date of the Martian calendar but that will not imply that the Earth calendar should be discarded and not used, for biologic as well as historic / cultural needs.

Soon specific events related to the constraints of living on Mars will be celebrated or paid a special attention to (arrival or departure dates of Space vessels, hidden days of the Earth / Sun conjunction period).

References:

"Technical Notes on Mars Solar Time as Adopted by the Mars24 Sunclock" by Dr Michael Allison (Mars24) NASA, Goddard Institute for Space Studies; https://www.giss.nasa.gov/tools/mars24/help/notes.html

Dual-time clock realized for Baselworld 2016 by Vaucher Manufacture Fleurier:

[1] Economist, retired corporate banker, President of the Mars Society Switzerland, member of the board of Association Planète Mars (the French branch of the Mars Society), Founding member of The Mars Society.

CURIOSITY ON MARS : WHAT IS NEW ABOUT ORGANIC MOLECULES ?

Michel Cabane[1]

In 2012, Curiosity, a NASA rover, landed on Mars. Here, some results of Gale Crater exploration will be presented, especially the methane concern (how to explain/reconciliate the various observations) and the quest for organic molecules (are there complex organic molecules on Mars ? what about habitability ?)

Key words: Mars, Curiosity, organic molecules, habitability.

Since September 2012, Gale crater, which results from a meteoritic impact, about 3.7 billion years ago, is explored by NASA's Curiosity that uses its robotics and science payload to obtain a better understanding of Mars story : geology, habitability.

For that purpose, two main features of the crater are of interest : (i) M^t Sharp (4500m height) at crater center, is the remains of a partial or total filling of Gale crater by sediments, dust, etc., followed by erosion : from its base to some kilometers height, geological strata are witnesses of Mars history (mineralogy, organic molecules) (ii) between M^t Sharp base and crater rim, the 'initial' crater floor shows alluvial fans and sediments due to water flows, æons ago. In both cases, concurrent presence of water, carbon bearing molecules, minerals will be an indicator for habitability.

Aboard Curiosity, SAM is mainly devoted to mineralogy and exobiology. The tunable laser spectrometer (TLS, JPL/NASA) measures CH_4 down to some tenths of a ppt, and may obtain isotopic ratios in H, C and O. The gas chromatograph (GC, Univ. of Paris/CNRS-CNES) and the mass spectrometer (MS, GSFC/NASA) analyze gases obtained from heating+pyrolysis of soil and rock samples, which provides clues about their composition (minerals and organic molecules). SAM detects down to 1 pmol of organic matter, i.e. about 0,5 ppb in the sample.

Atmospheric methane is of importance on Mars : if there is no current life on the planet, it only has a geologic origin that needs to be understood, but observations give contradictory results. Before Curiosity landing, observations gave a global CH_4 level from 10 to 60 ppb, with, in some cases, a high variability that has been contested *(Zanhle, 2010)*. From 2012, at Mars ground, Curiosity detected a very low CH_4 concentration (≈ 0.4 ppb), excepted for a few months, in 2014, where it climbed to values close to 10 ppb. More, in 2018, it was shown that the CH_4 background is a function of the epoch in the year, varying from 0.2 to 0.7 ppb (*Webster, 2018).* Up to now, no explanations exist and this will be discussed here, may be using new results from TLS/Curiosity or from spectrometers on ESA's Trace Gas Orbiter.

The presence of organic structures in sediments is now proven by the emission, after heating and pyrolysis, of complex organic molecules from mudstones : from 2014, C_6H_5Cl, $C_3H_6Cl_2$, etc. … have been found at pmol levels in 'Cumberland' *(Freissinet, 2015)* (presence of chlorine is due to the activity of soil perchlorates during heating), and C_2H_6S, C_5H_6S, etc. at nmol levels in 'Mohave' and 'Confidence Hills' *(Eigenbrode, 2018)* (sulfur indicates a possible role of sulfates in the preservation of organics). In July 2018, on M^t Sharp, Curiosity is exploring a hematite-rich layer ; a few weeks/months later, it will move to the next zone, where clay layers have been detected by orbiters. This will be of high interest, as far as clays play a very important role in prebiotic processes. All these results will be discussed, possibly in the light of new information coming from the rover.

References:

- Is there Methane on Mars ? Zanhle et al., *Icarus* **212**, 493-503, (2011).
- Background levels of Methane in Mars atmosphere show strong seasonal variations. Webster et al. *Science* **360**, 1093-1096 (2018).
- Organic molecules in the Sheepbed Mudstone, Gale Crater, Mars. Freissinet et al., JGR Planets **120**, 495-514 (2015).
- Organic matter preserved in 3-billion-year-old mudstones at Gale crater, Mars. Eigenbrode et al., *Science* 360, 1096-1101 (2018).

[1] emeritus, LATMOS, Sorbonne Université, campus UPMC, Paris

INDUSTRIE 4.0 TECHNOLOGY FOR THE BUILDING OF A FUTURE MARS CITY: POSSIBILITIES AND LIMITS OF THE APPLICATION OF A TERRESTRIAL TECHNOLOGY FOR THE HUMAN EXPLORATION OF SPACE

Antonio Del Mastro [2],Mario Tambos[1], Federico Monaco[1]

In the last years the development of Industry 4.0 has had a big impact on the advancing of some sectors of the terrestrial industry. This technology includes some key concepts which can be applied also in the future construction of human outposts on Moon and Mars.

We make here an analysis of the technologies of the Industry 4.0 and their possible use in the future human settlement of Mars and in the terrestrial Analogues. At same time we highlight the differences between the terrestrial technology and its possible use for the scope of the human exploration of Space.

The analysis wants to be an invitation to the terrestrial industry to consider what already has been developed on Earth as part of a wider process related to the human exploration of Space. As example of application of this analysis, some of the key concepts of the Mars City project are introduced.

Key words: industry 4.0, Mars City, IoT, MOCC, Space Economy

[2] Mars Planet- Via Dalmine, 10/A – 24035 Curno (BG) Italy. Info @ infomarsplanet.org

ADVANCED ELECTRIC PROPULSION FOR FAST MANNED MISSIONS TO MARS AND BEYOND

Angelo Genovese [1] *

One of the most serious challenges of human exploration of Mars lies in the long transfer time required, at least 180 days using chemical or nuclear thermal propulsion. A significant reduction in transfer time would relieve many issues, both technical and psychological, for human Mars missions.

High-power electric propulsion systems are probably the best candidate for near-future fast manned Mars missions. They can provide a specific impulse as high as 10 times the one given by chemical propulsion, leading to a significant reduction of the propellant mass. However, this translates into a significant reduction of the transfer time only if the mass of the power source is kept well below 10 kg/kW.

High-power nuclear electric power systems are considered as possible solutions to this problem. Today a space nuclear reactor can be realized with a specific mass of 30 kg/kW; however in the medium term, using advanced power-generation technologies that, while challenging, are considered feasible, for example a high-temperature Rankine conversion cycle, it could be possible to reach a specific mass of 5 kg/kW . This would allow a transfer time of about 120 days, 60 days less than the best transfer time with chemical propulsion.

A very fast Earth-to-Mars transfer in less than 120 days appears to be unrealistic in the medium term because it depends on a hypothetical breakthrough with the nuclear electric power source, requiring a specific mass that would typically be less than 1 kg/kW.

This paper also proposes an advanced electric propulsion concept, Laser-powered Electric Propulsion (LEP), where the nuclear reactor is replaced by a light-weight photovoltaic (PV) collector. A high-power laser beam from an in-space laser power source is aimed at the PV collector on the target spacecraft, where it is converted to electric power for an advanced electric propulsion system.

The PV collector/converter on the spacecraft can be tuned to the laser wavelength, thus achieving high monochromatic conversion efficiencies, currently ~ 50% with the potential to reach 80% in the near future. Such a light-weight power source could have a specific mass of less than 1 kg/kW, enabling very fast manned missions to Mars and beyond.

References:

Goebel, D. M. and Katz, I., “Fundamentals of Electric Propulsion: Ion and Hall Thrusters”, JPL/Wiley press, 2008
Berend, N., et al., “How fast can we go to Mars using high power electric propulsion?”, 48th AIAA Joint Propulsion Conference, AIAA-2012-3889, Atlanta, Georgia, 2012
Forward, R. L., “Advanced Propulsion Concepts Study: Comparison of SEP and Laser Electric Propulsion”, Final Report, JPL Contract 954085, June 1985.
Bett, A. W., Dimroth, F., Lockenhoff, R., Oliva, E., and Schubert, J., “III-V solar cells under monochromatic illumination,” 33rd IEEE Photovoltaic Specialists Conference, 2008
Genovese, A., “Advanced Electric Propulsion for Interstellar Precursor Missions”, book chapter in “Beyond the Boundary”, edited by K. Long and published by I4IS, 2014

[1] Initiative for Interstellar Studies, Ulm, Germany
*Corresponding author, angelo.genovese@i4is.org

THE AMADEE-18 MARS SIMULATION OMAN

Olivia Haider[1]

In February 2018, the Austrian Space Forum (OeWF) - in partnership with the Oman National Steering Comittee for AMADEE-18 - conducted the AMADEE-18 Mars analog field simulation, a highly international research project, involving over 200 people from 25 different countries. The test site in the Dhofar region in Oman shows geological features with a strong resemblance to geological structures found on Mars (e.g. dried out river beds). Hence, the test site provided a suitable analog to the Martian environment, enabling the execution of scientific experiments under high-fidelity conditions w.r.t. surface operations on Mars. Directed by a Mission Support Center in Austria, the carefully selected and trained field crew conducted experiments from various disciplines (engineering, planetary surface operations, astrobiology, geophysics/geology, life sciences) preparing for future human Mars missions. Mars analog field research in a representative environment is an excellent tool to gain operational experience and understand the advantages and limitations of remote science operations on other planetary bodies (Beaty 2007). Through the AMADEE-18 mission, the OeWF also implemented the Vienna Statement on Analog Planetary Research (OeWF 2016), which serves to catalyse and expedite the field of analog research.

Key words: Mars, Analog, Simulation, Oman, simulate Mars

During the AMADEE-18 Mars simulation in February2018, a field crew of 15 trained and certified people, including 6 analog astronauts, conducted 19 experiments in the fields of engineering, planetary surface operations, astrobiology, geophysics/geology, life sciences and other. The main focus was to i) study equipment, procedures and workflows for crewed surface operations under Mars analog conditions, ii) conduct experiments in the fields of geoscience, engineering and life sciences in order to iii) use the mission as a platform for emulating the search for life on Mars and iv) to increase the visibility of planetary sciences. All experiments were further embedded in a dedicated “exploration cascade” which pre-defines the sequence of the respective deployment to optimize the search for life on Mars.

All field activities were directed by a Mission Support Center (MSC) in Innsbruck, Austria. Based upon12 precursor Mars analog missions, the OeWF has established an MSC infrastructure with trained and certified flight controllers. The teams at the MSC were responsible for the overall mission execution, scheduling all field activities through the flight plan, coordinating the media activities and overseeing the analysis of the scientific data. The Earthcom position acted as a single point of contact between the MSC and the field crew in Oman. All communication was channelled through a 10-minutes time-delayed server, which simulated the average signal travel time between Earth and Mars. Furthermore, a dedicated Flight Plan team within the MSC was responsible for the scheduling of the field crew activities. The schedules comprised the daily activities of the field crew (on a 15-min. granularity), weather updates and traverse plans, which were describing the itinerary between the base habitat and the experiment locations for the analog astronauts.

References:

*Austrian Space Forum. “Vienna Statement on Analog Planetary Research”. Posted May 2016 by the Austrian Space Forum at http://oewf.org/wp-content/uploads/2016/05/The-Vienna-Statement-on-Analog-Planetary-Research.pdf

*D.W. Beaty, et al, “An Analysis of the Precursor Measurements of Mars Needed to Reduce the Risk of the First Human Missions to Mars”. Unpublished white Paper, 2007. p. 77. Posted June 2005 by the Mars Exploration Program Analysis Group (MEPAG) at https://planetaryprotection.nasa.gov/file_download/69/MHP_SSG_2005.pdf (17Aug2018).

[1] Austrian Space Forum (OeWF), member of the board

THE INTERPLANETARY TRANSPORT SYSTEM OF "SPACEX" REVISITED

Dr Pierre-André Haldi[1]

Critical analysis of the Interplanetary Transport System (ITS) architecture presented by Elon Musk (SpaceX) at the 2016 and 2017 International Astronautical Congresses; proposal of a somewhat different concept, aiming in particular at improving the safety/reliability of the whole system.

Key words: SpaceX Mars Project, Interplanetary Transport System Concept, Planet Mars Colonization

1. Strengths and weaknesses of the ITS architecture presented by SpaceX in 2016 (updated in 2017)

Like any fan of space exploration in general and that of Mars in particular, I followed with the greatest interest the fascinating presentation by Elon Musk of the SpaceX ITS project at the International Astronautical Congress in Mexico in September 2016. The proposed design of a massive launch vehicle and huge interplanetary spaceship were really impressive. Moreover, many innovative ideas such as a the full-reusability of all the components of the system and the concept of refueling the spaceship in orbit offer good and powerful perspectives for a more rapid colonization of the red planet than up to now considered. However, as an engineer (physicist) - although not a specialist in astronautics but with a good experience in risk analyses in particular - some aspects of this project looked at first sight rather puzzling to me, closer in fact to a science-fiction series like "Star Trek" than a realistic design of a spacecraft intended to transfer a hundred people from the Earth to the red planet, … and beyond (Jupiter and Saturn satellites)! This moved me to make a more thorough critical analysis of this proposal in order to identify what were in my opinion its strengths and weaknesses (e.g.: the too massive and "monolithic" conception of the system, the too high number of engines at the first stage of the launcher, the absence of a dispositive to create an artificial gravity during the flight, etc.), results of which I will present and discuss during this conference.

2. Proposal of an ITS of a somewhat different design aiming at improving in particular the safety/ reliability as well as the flexibility of the original system

Identifying possible weaknesses, or maybe even conceptual flaws, of a system design is one thing, but suggesting possible corrective counterproposals is of course better. I tried therefore to think of a somewhat different, and for me better, concept. The basic idea was to divide roughly by three the sizes of the main components of the originally proposed system, thus diminishing the development requirements and reducing in the same proportion the importance of the possible losses should an accident occur at launch time or during the interplanetary transfer. Instead of a "monolithic" spaceship, moreover fully integrated with the second stage of the launcher, I propose a more modular, and therefore flexible, system composed of six different component types, the last two being tripled: 1/ a booster-launcher more or less of the Saturn V or SLS class (i.e. 3-4 times less powerful than the original BFR of SpaceX) but reusable (RBL), 2/ an orbit-transfer propulsion module (TPM), 3/ an orbit-transfer energy module (TEM), 4/ an interconnection module (ICM), 5/ space habitation modules (SHM, 3x), ascent-descent vehicles (ADV, 3x, which could be reduced to one but at the expense of redundancy). The different modules will be assembled in space (and remain there, excepting for the RBL and ADVs), the connected (SHM-ADV)s in a 3 pointed-star configuration rotated to create an artificial gravity during the flight, More details on this ITS proposal will be provided during the conference.

References:

- Elon Musk's address to the 2016 *International Astronautical Congress* (IAC) in Guadalajara, Mexico, Sept. 27th 2016
- "Making Humans a Multi-Planetary Species", Elon Musk; Mary Ann Liebert, Inc., Vol. 5 No. 2 2017 NEW SPACE
- "The Case for Mars", Robert Zubrin; A Touchstone Book, ISBN-10: 0-684-83550-9, 1997
- "Entering Space", Robert Zubrin; Penguin Putnam Inc., ISBN: 1-58542-036-0, 2000

[1] Retired EPFL ("Ecole Polytechnique Fédérale de Lausanne") engineer-physicist, senior research scientist and lecturer; former director of the EPFL Post-graduate Course in Energy; former vice-president of the Mars Society Switzerland.

BEYOND HUMAN, TECHNICAL AND FINANCIAL FEASIBILITY, "MASS-PRODUCTION" CONSTRAINTS OF A COLONY PROJECT SURGE

Richard Heidmann[1]

SpaceX achievements and announcements push the prospect of a Martian colony more and more frequently under the spotlights. But proponents of this concept should acknowledge that mastering the technical means (including a low-cost interplanetary transportation system) and the behavioral and sociological unknowns does not address the whole story. Even within the limited scope of building a first operational colony of 1000 residents in 20 years - probably a minimal objective to attract investors - at least three major challenges emerge, which result from the mere volume of facilities to set up.

The most prominent is the problem of energy production, because the extraction and processing of in situ resources need much power. And furthermore, if BFR-like interplanetary shuttles are used, refueling alone will necessitate up to 0.5 MW of mean electrical power per ship! While nuclear generators look fit for a temporary exploration mission (about 50 kW), it becomes more difficult to satisfy needs for power levels in the MWs range. The reason is not the reactor itself, but the size of the cold source. Photovoltaics look simpler to implement, but with an order of magnitude of 50 W/m² of mean annual power, fields of several hectares (10 000 m²) are to be considered. The power in W/kg is a decisive parameter, but also the easiness of deployment and cleaning, as well as cells life duration.

Another dimensioning domain is the in-situ production of food, based mainly on cultivation inside greenhouses. If we admit that 60 m² of cultivated surface is required by person, for 1000 residents, the surface of the greenhouses themselves should be in the range of 10 hectares (100000 m²). That's a lot. The actual scale depends on the chosen technologies, namely: natural vs artificial light (requiring tens of MW of electrical power), and plain soil vs hydroponic cultivation. The chosen atmospheric pressure is also a determining parameter for the total mass of the greenhouses.

The habitats constitute the third category of facilities which should be set up on a large scale. Our "realistic" hypothesis of a 1000 residents size in 20 years implies to add, as a mean value, an individual lodging capacity per week. The problem is even more demanding if the offer of residency services (for wealthy tourists and scientists) is the only scenario that we have for a financially plausible project. Because tourists would not like to spend their 18 months stay underground; more sophisticated architectures will be needed. A variety of technologies had been surveyed: tunnels, brick masonry, glass panels, inflatables, 3D printing… But their value at this "industrial" scale, in terms of consumption of manpower, energy and imported materials, remains to be more precisely estimated.

[1]*vice-president of Association Planète Mars (* heidmann.r@orange.fr), former director at SNECMA, graduate of Ecole Polytechnique and SUPAERO.

EUROPEAN MANNED SPACE PROJECTS

Jürgen Herholz[1]

The presentation focuses on the European participation to the ISS program with COLUMBUS and the ATV, and plans for manned space transport systems such as HERMES, SÄNGER, SPACELINER, HOTOL/SKYLON. Initially a short overview is given on the manned space achievements of the USA, which originated after World War II from European research work and rocket development by Werner v. Braun and his team and resulted in the APOLLO program. The projects SPACELAB and ARIANE 5 / HERMES -which the author joined from 1972 to1987 at industry and from 1987 to 1998 at ESA- are addressed in more detail.

Key words (in chronological order): Hypersonic Research, Apollo, Skylab, Shuttle-Spacelab, Ariane5-HERMES, ARD, Sänger, ATV, Columbus, Orion, Spaceliner, Skylon.

Presentation Outline

The first rocket capable of space transport was developed in Germany by Wernher v. Braun, who conceived and directed after the war the APOLLO program of the USA. Later on the USA confirmed their leadership in manned space with the SPACE SHUTTLE, the International Space Station ISS, plans for deep space missions such as ORION and recently the Mars human settlement plans of Space X.

As part of the NASA SPACE SHUTTLE program NASA proposed 1972 to Europe to participate with the research laboratory SPACELAB as main SHUTTLE payload. SPACELAB was then developed and built in Europe from 1974 onwards and flew in 22 successful manned scientific research missions with the SHUTTLE. SPACELAB had a modular design with a manned module and so-called "pallets" capable of carrying a variety of payloads exposed to open space. The SPACELB module was to a large extent an autonomous space habitat. Two SPACELABs were delivered to NASA in the 80's, with the first mission of the manned laboratory in 1983. SPACELAB was a success story providing Europe the competence for manned space systems design and construction, enabling Europe to join 1995 the ISS program with the COLUMBUS scientific research laboratory attached to the ISS. The ATV, another European contribution to the ISS program, although unmanned, proved Europe's capacity to build vehicles meeting manned safety standards allowing direct docking to the ISS.

Initially, from 1985 onwards Europe developed, under the leadership of ESA, plans for an independent manned space and ground infrastructure with a free-flying microgravity research laboratory called MTFF (Man-Tended-Free Flyer), based upon SPACELAB technologies. The MTFF should be serviced by the manned spaceplane HERMES.

While the MTFF was abandoned in favor of COLUMBUS, HERMES achieved a quite detailed definition status based on design and predevelopment work performed between 1980 and 1992 under the leadership of CNES and ESA. In 1992 the HERMES program was terminated along with plans for an independent European manned space infrastructure, in the political turbulences after the "fall of the iron curtain" in 1989. HERMES technology related research, fabrication and test continued however up to 1998, with an Atmospheric Reentry Demonstrator (ARD) developed on the basis of HERMES technologies. 1998 the ARD was successfully launched by ARIANE 5, demonstrating Europe's capacity for a reentry vehicle similar to the APOLLO capsule.

Europe remained however always engaged in manned space transport in the area of hypersonic research and the conception of manned space planes. The participation in the NASA ORION deep space program with the European Service Module ESM, studies on the large spaceplane SÄNGER performed in Germany from 1988 to 1992, and the ongoing studies of the manned space transportation systems SPACELINER and SKYLON underline Europe's interest and competences in conceiving manned space transportation systems.

References

1- Technical and programmatic documents stemming from work of the author at industry and ESA
2- Numerous data and images retrieved via internet incl. from WIKIPEDIA

[1] Dipl.Ing./Mars Society Germany board member/participation in Spacelab, Ariane5-Hermes, ISS, ATV and Columbus programs

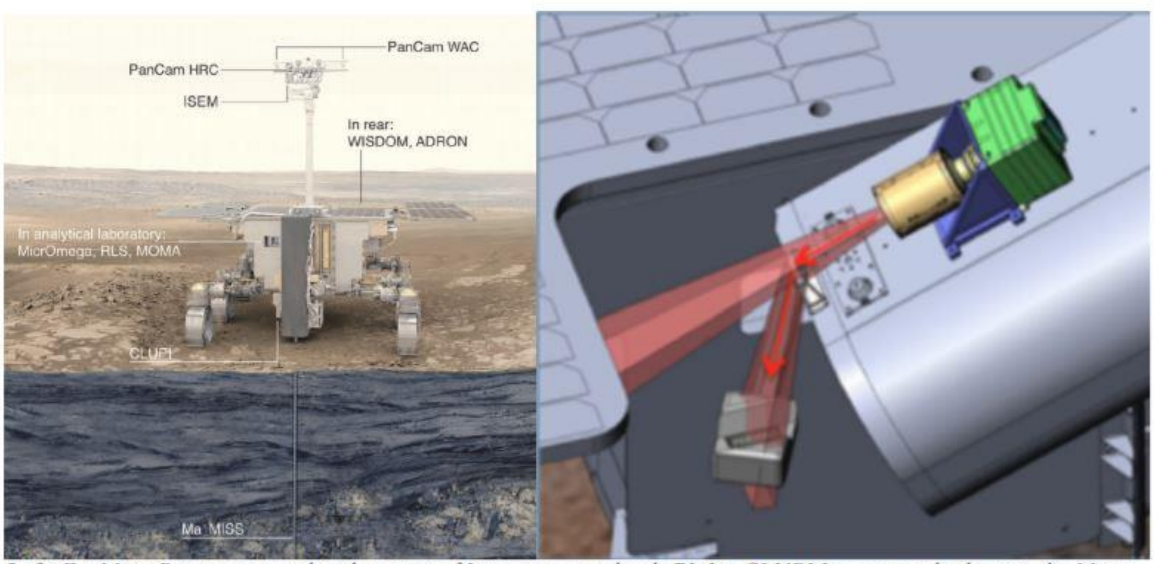
SEARCH FOR LIFE ON MARS, THE EXOMARS ROVER MISSION AND THE CLUPI INSTRUMENT

Jean-Luc Josset[1] and the CLUPI Team

Key words: ExoMars, CLUPI, Astrobiology, Biosignatures

The presentation will address the ExoMars 2020 rover mission in a first part and focus on one of the key science instruments CLose-UP Imager CLUPI accommodated on the drill box of the rover. The ExoMars rover will travel across the Martian surface to search for signs of life. It will collect samples with a drill and analyse them with next-generation instruments. ExoMars will be the first mission to combine the capability to move across the surface and to study Mars at depth down to 2m.

The ExoMars Mission 2020 is a joint astrobiology mission of the European Space Agency (ESA) and the Russian space agency Roscosmos to search for evidence of life on Mars. The mission, with a Proton rocket launch date of July 2020 and a Mars landing date of Mars 2021, will deliver a Russian surface platform and a European rover to the surface of Mars equipped with various instruments for investigating the surface and, for the first time, the subsurface of Mars until 2m of depth. One of these instruments –a CLose-UP Imager called CLUPI– will allow for taking images to obtain visual information similar to that from a geologists hand lens.
The CLUPI instrument on-board the ESA ExoMars Rover is a powerful high-resolution color camera specifically designed for close-up observations. Its accommodation on the movable drill allows multiple positioning. CLUPI will contribute to the rover mission by surveying the geological environment, acquiring close-up images of outcrops, observing the drilling area, inspecting the top portion of the drill borehole (and deposited fines), monitoring drilling operations, and imaging samples collected by the drill.
The science objectives of the instrument are geological characterization of rocks in terms of texture, structure, and color and the search for potential morphological biosignatures. We present the CLUPI science objectives, performance, and technical description, followed by a description of the instrument's planned operations strategy during the mission on Mars.



***Left**: ExoMars Rover equipped with a suite of Instrument payload; **Right**: CLUPI Instrument looking at the Mars sample in the drawer before analysis in the laboratory inside the rover*

[1] Research Scientist, PhD in Physics, Director of the Space Exploration Institute, CLUPI Principal Investigator, ExoMars 2020

SEIS/INSIGHT: TOWARD THE SEISMIC DISCOVERING OF MARS

P.Lognonné[1] and the InSight/SEIS Team.

The NASA InSight (Interior Exploration using Seismic Investigations, Geodesy and Heat Transport) mission will land on Mars on November, 26th after a launch on May, 2018. The payload is a complete international geophysical observatory, with a seismometer (SEIS, France), a heat flux experiment (HP^3, Germany), a geodesy experiment (RISE, US), a magnetometer and the APSS (US) suite of atmospheric sensors measuring wind (TWINS, Spain), atmospheric temperature, pressure and magnetic fields. SEIS is the primary instrument of the mission and consists of a 3-axis very-broad-band (VBB, France) instrument and a 3-axis short period (SP, UK) instrument, mounted on a Leveling system (LVL, Germany), connected to acquisition and control electronics (Ebox, ETHZ from Switzerland) by a Tether (US), and protected by a Wind and Thermal Shield (WTS, US). The SP noise floor is $3\ 10^{-9}$ $m/s^2/Hz^{1/2}$ between 0.1 and 6 Hz and significantly better than SP requirements (10^{-8} $m/s^2/Hz^{1/2}$ between 0.1 and 10Hz). The VBBs are enclosed in a vacuum thermal enclosure (EC) under JPL responsibility, which not only provides a high thermal protection for the VBBs but also reduces their Brownian noise, enabling the VBBs to reach a very low noise floor of $3\ 10^{-10}$ $m/s^2/Hz^{1/2}$ between 0.1 and 1 Hz, which is also significantly better than VBBs requirements (10^{-9} $m/s^2/Hz^{1/2}$ between 0.01 and 1Hz).

We describe first the SEIS experiment and present its science goals and performance demonstrated during the Flight Model characterization done during the 2017 Flight Model delivery activities, both in the clean rooms of CNES and LMA for the Flight Units and in the Black Forest Observatory seismic vault for the qualification unit. As SEIS is expected to provide the first seismic records of Mars, implementation of the science goals has been very challenging due to the lack of information on the deep seismic interior structure of Mars, as well as its level of seismic activity and surface seismic noise. Nevertheless and in parallel with the hardware technical developments made by the SEIS hardware team, the SEIS science team has developed sophisticated noise models, blind tests with synthetic data and field tests, including during activities of the HP3 mole system, which will be presented.

We then summarize and review the most recent analysis made by the SEIS team for predicting the seismic performance of the SEIS experiment in the Martian environment, including pressure and magnetic decorrelations using APSS sensors. We present the most recent update estimates of seismic signals generated by quakes, impacts and the Martian dynamic atmosphere, as well as structure inversion and seismic catalogue perspectives. We conclude by describing the Public Outreach and Educational program of SEIS.

[1] IPGP-Sorbonne Paris Cité, Univ. Paris, France Diderot (lognonne@ipgp.fr)

FROM THE EARTH'S STRATOSPHERE TO FLYING ON MARS

- a few experiences from the SolarStratos project for the exploration of the Martian atmosphere -

Roland Loos[1]

The SolarStratos project has built a manned aircraft to fly a pilot to Earth's stratosphere up to 20 – 25 km altitude powered by solar energy only. Comparing "solar flying conditions" at low altitudes on mars with those in the Earth's stratosphere, some parallels can be drawn and lead to a solar aircraft to explore the Martian atmosphere.

Key words: Martian atmosphere – to explore – solar aircraft - solarstratos

1. Flying solar

With a fully deployed wingspan of 25 m and a total weight of around 600 kg, the Solarstratos aircraft aims to reach the stratosphere up to 25'000 m in the coming years. The pilot will wear a russian sokhol space suit and the electrical engine will be powered by solarcells on the wings and horizontal tail.

Follow-on versions will be unmanned drones flying long duration stratospheric flights above flight level 600 with telecom, earthobservation and other potential payloads.

2. Flying solar on mars

Comparing

- the lower solar energy available on mars
- but also the lower gravity
- and the atmospheric density at low altitude (datumline)

one can imagine an unmanned solar powered aircraft flying at low martian altitudes in similar flying conditions as on earth in the stratosphere.

We thus can conceive a solarpowered aircraft, with vertical take-off and landing capability, to take off in the morning, as the sun rises, fly, do its mission with whatever payload included and land again at sunset.

In order to sustain atmospheric flight in the low density atmosphere, ground speed will be a few hundred km/h, provided by a solarpowered electrical engine. Hoping around at several hundred kilometers per day, large areas can be covered.

Right now, the priority of our team is to fly in the Earth's stratosphere and manage the challenges of low air-density flying; but this presentation will give some more glimpses on the potential of solarpowered unmanned flight in the Martian atmosphere to cover long distances, thus extending the range of research done by ground based rovers.

[1] ing. dipl. EPFL – business angel and CEO of the Solarstratos project – member of the Mars Society Switzerland

CURRENT RESEARCH IN TIME & FREQUENCY AND NEXT GENERATION ATOMIC CLOCKS

Gaetano Mileti[1]

Many applications and scientific experiments, on ground and in space, require accurate and/or stable time & frequency references that can be provided only thanks to atomic clocks. Even though a few companies produce them industrially, these precision instruments are still subject of fundamental and applied research.

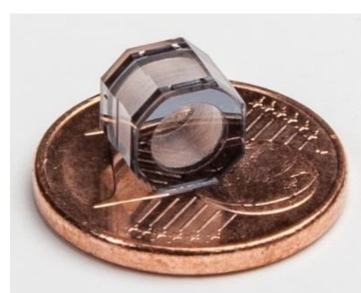
Key words: atomic clocks, time & frequency, lasers.

1. Principle of atomic clocks and applications

In an atomic clock, the frequency of a quartz oscillator is stabilised by using a well-selected atomic transition as a reference. The basic physical phenomenon at its heart is generalised Nuclear Magnetic Resonance (NMR). This NMR-like system can be realised in various ways, by exciting atoms stored in a vapour or in a beam, and may involve different elements such as Rubidium, Cesium, Hydrogen, etc. The precision and the stability of each atomic clock depend on its practical realisation and on the available spectroscopic and metrological data. Thus, various types of atomic clocks were developed during the last decades, by selecting the implementaion of the NMR principle and the employed technologies that will match the specific need of each application: fixed and mobile telecommunications, network synchronisation, smart grids, underwater seismic exploration, satellite positioning and navigations, etc.

2. Examples of current research

Atomic clocks still constitute a very active field of research that is simulteneously close to fundamental research, to technological developments and to everyday life applications. In the second part of our presentation, we will summarize the main axis of this worlwide effort, aiming to better understand the basic physical phenomena, to exploit the newly available technologies and ultimately to improve the performances of atomic clocks while expanding the range of their applications. The area of Neuchâtel has been particularly active in this field and still constitutes a unique concentration of research laboratories and of companies operating in the domain of *„Time and Frequency"*. We will conclude our talk by presenting a few examples of research projects towards next generation atomic clocks.



Left*: prototype of laser-pumped Rubidium atomic clock for next generation satellite navigation system (Galileo).*
Upper right*: glass-blown Rubidium vapor cell for laser wavelength stabilisation (for atomic clocks and Lidars).*
Lower right*: micro-fabricated Rubidium vapour cell for next generation chip-scale atomic clocks.*

[1] Professor of Physics at the University of Neuchâtel. Co-founder and deputy director of LTF (Laboratoire Temps-Fréquence).

TETHERS AND POSSIBLE APPLICATIONS FOR ARTIFICIAL GRAVITY PRODUCTION IN SPACE

Claude Nicollier[1]

Claude Nicollier has not yet provided his abstract but he told me that he will talk mostly about tether behavior in Space and secondarily about artificial gravity production.

As you may know Robert Zubrin in its first book ("The Case for Mars") proposed that (1) the habitat of a manned mission and the last stage of its launcher be linked together by a tether (after the last stage has completed its combustion); (2) that the couple thus created, be rotated (small impulsions at the level of the habitat and of the last stage of the launcher) in order to create artificial gravity inside the habitat during the flight, the intensity of the internal artificial gravity being increased by shortening the tether.

In this context the knowledge of the behavior of a tether is absolutely essential and Claude Nicollier had the experience of such behavior during one of his space flights.

Pierre Brisson

[1]Astrophysicist, Swiss Astronaut, Professor at the EPFL, member of Honour of the Mars Sociey Switzerland

FIRST RESULTS FROM THE COLOUR AND STEREO SURFACE IMAGING SYSTEM (CASSIS) OF EXOMARS TRACE GAS ORBITER (TGO)

Antoine Pommerol[1] and the CaSSIS Team

I will present the concept of the CaSSIS instrument that has been imaging the surface of Mars from orbit since April 2018 and discuss some of the early results.

Keywords: Mars, surface, imaging

1. Exomars Trace Gas Orbiter

The Colour and Stereo Surface Imaging System (CaSSIS) is one of the four scientific instruments of the Trace Gas Orbiter (TGO), the first step of ESA's Exomars program and the latest addition to the fleet of spacecraft scrutinizing the surface of Mars from orbit. The overarching scientific goals of the TGO are to measure the atmospheric composition of the Martian atmosphere with very high precision and to look for possible sources for the trace gases at the surface or in the subsurface. Trace gases are indeed key for our understanding of current geological and possibly biological activity on Mars as they could be the products of volcanism, hydrothermal activity or metabolism. The TGO also supports other current and future missions by providing communication relay for lander and rovers and by characterizing and certifying possible future landing sites.

2. CaSSIS

CaSSIS is the scientific imager of TGO and supports the scientific and technological objectives of the mission by imaging the surface of Mars with a resolution of 4.5 metres per pixels, in up to four colours and in stereo, in order to retrieve quantitatively the topography of the surface. CaSSIS was built at the University of Bern with hardware contributions from the University of Padova (Italy) and the Space Science Center of Warsaw (Polland). Colour images are recorded by a 2048x2048 pixels CMOS detector covered by four colour filters at the focus of an off-axis four-mirrors telescope with a 13.5 cm primary mirror. This optical system comprising the telescope and the detector is mounted on a rotation mechanism that serves two purposes: compensate for the rotation of the spacecraft and allow for stereo imaging by taking two images of the same targets from two different positions on the orbit.

After presenting the concept of the instrument, I will show a selection of some of the first images acquired from the nominal science orbit since April 2018 and discuss briefly the scientific questions behind these images. Some of the themes covered will be: the ancient alteration of the Martian crust by water, the current Martian climate, the diurnal and seasonal volatiles cycles.

References

Roloff, V. et al., On-Ground Performance and Calibration of the ExoMars Trace Gas Orbiter CaSSIS Imager, Space Science Reviews, 212, 1871-1896, 2017.
Thomas, N. et al., The Colour and Stereo Surface Imaging System (CaSSIS) for the ExoMars Trace Gas Orbiter, Space Science Reviews, 212, 1897-1944, 2017.
Tulyakov et al., Geometric calibration of Colour and Stereo Surface Imaging System of ESA's Trace Gas Orbiter, Advances in Space Research, 61, 487-496, 2018.

[1] Dr. Antoine Pommerol, University of Bern

ATOMIC CLOCKS AND TIMING SYSTEMS IN GLOBAL NAVIGATION SATELLITE SYSTEMS

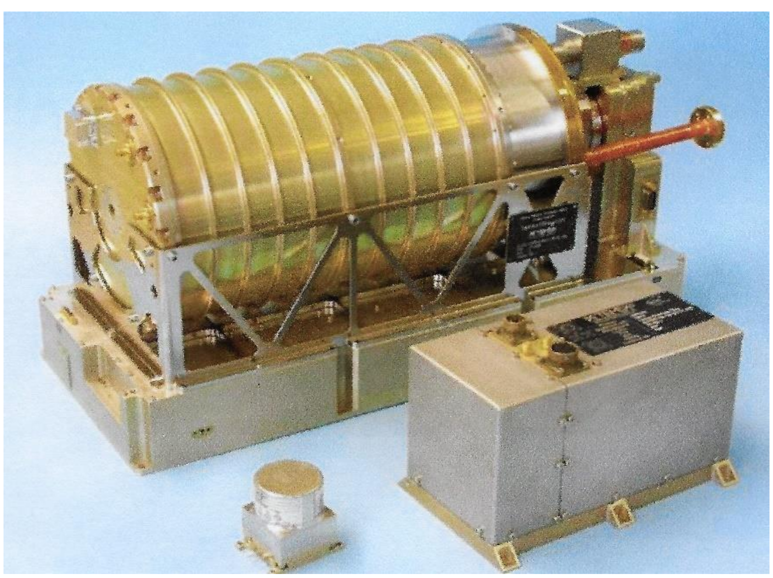
Pascal Rochat [1]

Accurate and ultra-stable atomic clocks have been recognized as the critical equipment for the precision Global Navigation Satellite Systems (GNSS). SpectraTime (SpT) and T4Science (T4S) are space and ground clocks manufacturers of Rubidium Atomic Frequency Standard (RAFS) and Active & Passive Hydrogen Maser (HM) for various navigation systems (European, Chinese and Indian) and other programs.
More than 100 SpT RAFS more than 50 Passive HM units are flying around the globe. As for ground application, more than 24 T4S Active HMs are involved in different GNSS ground segment worldwide, and one passive HM is in progress in the frame of a ground development program.

Key words: Global Satellite Navigation System.

This paper describes for space RAFS and HM performances and life-time tests, as well as onboard clock performances.

A short overview of the ground GNSS timing reference segment with its active Masers and associated disciplining algorithms will be given. Even these standard Rubidium and maser technologies have been proven to be highly reliable and robust those could be subject to perturbations and could exhibit some anomalies , especially when exposed to single event radiations , magnetic field perturbations etc…. With those elements in hands, a presentation of novel onboard techniques to generate highly robust timing signal directly from the satellite onboard One CLock Ensemble (ONCLE) is presented. Performances achievements in presence of perturbations, and frequency jumps are also shown allowing a continuous and uninterrupted operation of the satellite navigation signals.
Futher developpement of the next generation of Galileo Clock like mini-Maser, RAFS II & Mercury Ions trap clocks will be described as well of possible new techniques using LEO satellites combining booth navigation & communication ,taking benefits of mini-Rubidium recently designed and already tested under radiations .



[1] Pascal Rochat , Managing Director / Founder of Orolia Switzerland (Spectratime) & T4Sience.

EUROPEAN HUMAN MISSION TO MARS

Jean-Marc Salotti[1]

Mission architecture for a European human mission to Mars based on a super heavy Ariane Launcher

Key words: human mission to Mars, Ariane Super Heavy

1. Main principles

This presentation is based on a paper presented at the International Astronautical Congress that took place in Bremen in early October 2018. As suggested by a preliminary study from CNES, a heavy version of the Ariane launcher can be used for a human mission to Mars [1]. This enhanced Ariane has 100 metric tonnes LEO capability and 36 metric tonnes capability for transMars injection (Vinfini=3.5km/s). In order to simplify the scenario and minimize the costs, it is proposed a pre-deploy semi-direct architecture with several rather small spaceships and the implementation of aerocapture for Mars orbit insertion [2]. There are several advantages: First, as the payload to the Mars surface is split in equal parts between 34 and 36 metric tonnes, the same landing space vehicle can be used with mass and size compatible with the payload capability of the launcher. Second, the choice of relatively small landers allows the use of simple deployable rigid heatshields, which could be used both for aerocapture and entry, descent and landing. The use of small landers also reduces the complexity of the tests for the qualification of the descent and landing systems and procedures, which is a critical aspect of the preparation phase. 5 Ariane are required in this architecture.

2. Architecture

According to our calculations, which are derived from NASA numbers, for a crew of 3 astronauts, this architecture requires only 5 super heavy Ariane launches:

- The first payload is the Mars ascent vehicle that is directly sent to the Martian surface 2 years before the crew. As suggested by NASA, it includes a tank already filled with methane but the oxygen is produced on site exploiting the carbon dioxide of the atmosphere.
- The second payload is a backup habitat with surface vehicles and consumables for 500 days. It is also sent 2 years in advance 2 years before the crew by means of a single super heavy Ariane launcher.
- The third and fourth payload are the two parts of the Earth return vehicle, which are a habitable module with consumables for the return and a propulsion system attached to a Earth reentry capsule. Both are directly sent to Mars orbit separately and fixed together there.
- The fifth payload is the human space vehicle that is directly sent to the surface of Mars.

References

[1] D. Iranzo-Greus C. Chavagnac, C. Talbot, J. N. Couteau, J. M. Conrardy, The European launcher option for exploration, proceedings of the International Astronautical Congress, IAC-06-D2.7./A3.7.07, Valencia, Spain, 2006.
[2] J.M. Salotti, Robust, affordable, semi-direct Mars mission, Acta Astronautica, Volume 127, October–November, pages 235–248, 2016.

[1] Professor at Ecole Nationale Supérieure de Cognitique, Laboratoire de l'Intégration du Matériau au Système, CNRS, INRIA, Bordeaux INP, Association Planète Mars

ZERO-GRAVITY:
THE FIRST WATCHMAKING COMPLICATION OF THE SPACE AGE

(http://www.0g-complication.ch)

Alain Sandoz[1]

As a tribute to the beauty of fine mechanics exposed at the International Watchmaking Museum of la Chaux-de-Fonds and to the pursuit of space exploration, we present a mechanical device that measures the time spent in weightlessness: Zero-Gravity, a watchmaking complication of the space age.

Key words: watchmaking complications, measuring time, weightlessness, mechanical devices

According to the Foundation of High Horology a watchmaking complication is "... *any function* [of a watch] other than the indication of hours, minutes and seconds, regardless of whether the mechanism is hand-wound or self-winding, mechanical or electronic, ...". The number of existing complications does not exceed a few dozens, among which astronomical indications (moon phases, equation of time, movement of planets, for example) are related to celestial mechanics.

Amateurs of watchmaking complications have devoted their fortune to collecting such beautiful mechanical devices, but watchmakers and collectors alike have seldom been found to be travelling in space. Weightlessness would have prevailed in their journey and inventing a mechanism for their watches to measure the time spent in that state would no doubt have challenged their minds.

Measuring the time spent in the state of weightlessness defines a new type of complication: de facto the first watchmaking complication of the space age. The short ludic presentation of the Zero-Gravity complication at EMC-18 sketches this invention and intends to bring together the old world of the mechanical devices exposed in the Museum and the new world that humans are dreaming of in order to make travel to the planet Mars possible.

References

« Clock device for measuring the time spent in weightlessness », Alain Sandoz, Tom Josset, WO 2017/137926 Al, DEMANDE INTERNATIONALE PUBLIEE EN VERTU DU TRAITE DE COOPERATION EN MATIERE DE BREVETS (PCT), Feb. 2017

[1]Information systems engineer, Associate Prof., Informatics Institute of the University of Neuchâtel, co-inventor of the Zero-Gravity watch-making complication.

TIMING CONSTRAINTS FOR MARS MISSIONS: EXAMPLE OF COMMUNICATIONS COMMANDS FOR EXOMARS CLUPI INSTRUMENT

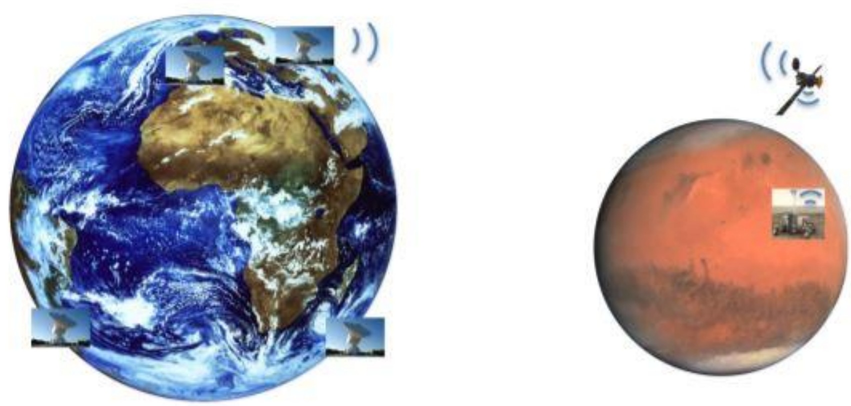
Mitko Tanevski[1]

The ESA ExoMars 2020 Rover contains numerous instruments CLUPI being one that generates large amounts of data, the communication is aggregated and relayed to earth – the challenges are multiple

Key words: CLUPI, ExoMars 2020, CLUPI communication commands, CLUPI mission operations planning

1. ExoMars mission communication with Earth

The ExoMars 2020 rover shall have a telecommunications link with the earth for receiving the daily telecommand plans and for transferring the maintenance and scientific telemetry from Mars down to Earth. The link would nominally use the Mars Trace Gas Orbiter (TGO), although the use of other orbiters is possible. From the orbiter the signal is then directly transmitted to Earth based antennas. The pace of communication and its organization is influenced by many parameters and in this presentation an overview is given on these parameters and on the foreseen mission communication planning.



2. CLUPI Instrument communication with the Rover

The CLUPI instrument has a communication interface to the Rover. The Rover software unpacks telecommands and operates CLUPI according to the daily plan for each day of the mission. Similarly, all CLUPI telemetry is aggregated with other data on the Rover, compressed, and send back to Earth. CLUPI operations have a defined time and power consumption profiles as well as predefined windows of execution in function of the available bandwidth, ambient temperature, ambient light, and available power.

References

ESA ExoMars Trace Gas Orbiter (TGO) http://exploration.esa.int/mars/46475-trace-gas-orbiter/
ESA ExoMars Mission overview http://exploration.esa.int/mars/48088-mission-overview/
Space-X Exo Mars Mission overview http://www.space-x.ch/missions/exomars/
Space-X CLUPI instrument overview http://www.space-x.ch/missions/exomars-clupi/

[1] Electronics & Communications Eng. Expert, CLUPI Science Operations Manager ExoMars 2020, ESA Mars Rover Mission, Space Exploration Institute (Space-X)

DESIGN OF A MARS POLAR RESEARCH BASE WITH A CRANE SYSTEM

Anne-Marlene Rüede[1], Anton Ivanov[2], Claudio Leonardi[3], Tatiana Volkova[4]

Key words: Mars, Polar Layered Deposits, Human Exploration, Research Base, In-Situ Resource Utilization, Mission Architecture, Ascent & Descent Vehicle

The ice from the Martian North Pole is estimated to contain information on the formation of Mars, its climate and is also a great candidate for searching for extra-terrestrial life traces in the Solar System. Despite this, its secrets are yet to be unveiled by mankind. To do so, ice samples must be extracted by drilling and analyzed in-situ. Additionally, the Northern polar regions of Mars also hold the potential to harbor human life, as the polar cap constitutes a water reservoir. Therefore, proposing a crewed mission to the Mars North Pole would greatly advance the resolution of sub-objectives in all main goals set for the exploration of Mars by NASA in 2015. But how could such a mission be executed and what could the base be like?

This talk proposes to look at the design of a mission scenario and base with high technology readiness level that could sustain a crew of six near the North Pole of Mars, during Martian summer. It allows the crew to drill for and analyze ice samples in a laboratory located on the planet. The possibilities offered by in-situ available resources and the selection of a strategy for constructing the base, life support system and in-situ propellant production will be discussed. Furthermore, all design steps necessary to guarantee the security and successful operation of the mission will also be presented.

In the conclusion, the key technologies that still need to be developed in order to allow for humans to wander to Mars are presented, along with a proposition to include several experiments in a first generation crewed mission on Mars to facilitate a long-term presence of humans on the planet.

Furthermore, as a consequence of the requirements identified during the design of the mission, it has become apparent that a crane system for trasnfer between Mars' orbit and surface is required and could even benefit other crewed or robotic missions. Therefore, a concept for a Mars crane system is also presented in this talk.

[1]Department of Architecture & Space Engineering Center (eSpace), Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland, anne-marlene.ruede@epfl.ch. (*student*)
[2]Space Engineering Center (eSpace), Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland & Space Center, Skolkovo Institute of Science and Technology, Russia, anton.ivanov@epfl.ch.
[3]Informatics and Visualization Laboratory (LIV), Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland, claudio.leonardi@epfl.ch.
[4]Swiss Space Center, Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland, tatiana.volkova@epfl.ch. (*student*)

DESIGNING A 10-TON PAYLOAD MARTIAN LANDER

CHANTEBEL Clement[1], COMBY Leopold[1], LENORMAND Maxime[1], SABADIE Anais[1]

We are a team of 4 French students from IPSA, an aerospace engineering school in Paris; and we took place in the international student contest 'Red Eagle' held by The Mars Society to design a 10-ton payload Martian lander, capable of being build and send by 2026. Our design has made it to the semi-finals of, to be held at the end of August. Our idea is based on creating two landers, a smaller, cheaper one that would fit the Falcon Heavy, and a bigger, crew-capable lander able to launch using NASAs' up-coming Space Launch System (SLS).

Key words: student, contest, lander,

1. An overall study

The aim of this contest was to ask to students world-wide what ideas they might have for designing landers for heavy payloads on Mars. The study would only be for the Entry, Descent and Landing (EDL) phase of the flight, not actually getting to Mars, and in orbit around it. All of this required a schedule plannning, but also a cost approximation, as well as, of course, mainly a technically study of the feasability of our designs. In order to perform such work we used multiple tools, first of all we got in touch with the French branch of TMS, Association Planete Mars, in order to have access to studies and work already done the topic. We also were helped by Jerome Daniel, a member of the Association, which made a software calculating different data for EDL depending on a landers' geometry and trajectory. We couple this with some student version (understand limited) Computer Fluid Dynamics software and a heavily modded verison of Kerbal Space Program to perform simulations of the landings. All of this allowed us to be able to prove, at least on paper with a first study, that our ideas looked feasible.

2. Two different Landers for two different missions.

Our main idea was to have a first ‚lighter' lander, that we would be able to launch using the cheaper Falcon Heavy. This lander would then perform an aerobraking maneuver in order to lower its velocity and orbit around the Red Planet. This would allow for important reduction in fuel requirements, allowing to land a bigger payload with the same launch capability. All of this would be at the expence of time, since aerobraking requires multiples passes through the atmosphere to slow a lander down. The end of the landing would then be a conventional burn to get the payload smoothly on the ground.

This is why there would be a bigger lander, capable of actually landing crews, that would be more ‚traditionnal', since it would do most of its landing using a heat-shield and retro-burn. Though both of our landers would use Inflatable Aerodynamic Deccelerators (IADs), a sort of reverse umbrella allowing for a much bigger friction surface when entering the atmosphere, as it is much thinner than of Earth.

References

ZANG & DWYER-CIANCIOLO, KINNEY & HOWARD, CHEN & IVANOV & SOSTRAROC & WESTHELLE, *Overwiew of the NASA Entry, Descent and Landing System Analysis Study*, 2011

NASA, *Entry, Descent and Landing Systems Analysis*, Phase 1 : Report ; NASA, July 2010

Overview of the NASA entry, Descent and Landing Systems Analysis Study, post 2011

BRAUN R. D., MANNING M., *Mars Exploration Entry, Descent and Landing Challenges*, 2006

MARTIN, Paul K., *NASA's Management of the Mars Science Laboratory Project*, National, Audit Report, Aeronautics and Space Administration (NASA), June 8, 2011

ED Kyle, *NASA's Space Launch System*, June 02, 2017

[1]students at IPSA, aeronautic and astronautic engineering school in Paris and Toulouse

PROPOSAL OF DAILY (CLOCK) AND YEARLY (CALENDAR) TIME DIVISIONS FOR FUTURE MARS COLONISTS

Dr Pierre-André Haldi[1]

Besides the terrestrial system of temporal references that they will have to keep for their contact with the Earth and certain other applications, the future Martian settlers will require a local system adapted to the astronomical parameters of their new planet. Such a system, suitable for a practical use, is presented here.

Key words: Martian clock, Martian calendar

Preliminary note: Clock and calendar should suitably **rhythm** the daily life of the future martian settlers, which implies to keep some regularity in the divisions of time, daily as well as yearly.

3. Martian daily (clock) time division

The daily division of time on Mars must obviously take as basis the length of the Martian day (24 h 39 min 35 s). This martian day is usually refered as "sol", but I suggest replacing it with "marsol", which is less confusing ("sol" doesn't call to mind Mars but rather the sun, even worse "sol" in French means "ground"!) and more consistent with the names of the subdivisions I propose: "marsur" = 1/24th "marsol", "marsin" = 1/60th "marsur", "marsec" = 1/60th "marsin". These names have the advantage of avoiding any confusion with rhe corresponding terrestrial units, and moreover to be easy to pronounce in most languages and also easy to memorize (close connection with the corresponding terrestrial unit names).

4. Martian yearly (calendar) time division

For the division of the Martian year, I propose to take for base an equal length of the months of 28 marsols, reduced to 27 marsols every sixth month. With the addition of one marsol at the end of each even year (which will thus remain at 28 marsols) to better fit with the real length of the Martian year of roughly 668 and a half marsols. Such a system is easy to use, not far from its terrestrial counterpart, suitable with monthly schedules (e.g. paying of salaries) and even more regular than our actual terrestrial calendar! Even if the months don't precisely coincide in this scheme with the alternation of the seasons because of the ellipsity of the Martian orbit, this will be of little importance (the Martian colonists will not essentially be farmers or astronomers and, moreover, it is also the case on Earth!).
There remains a problem however, the precise length of the martian year being 668.6 marsols, there will be a progressive shift between the martian calendar year and the real martian year. This is however easy to solve, it is sufficient to add one marsol at the end of every ten years ("leap" year) and the agreement will then be almost perfect (better than in the case of the terrestrial calendar)!

[1] Retired EPFL ("Ecole Polytechnique Fédérale de Lausanne") engineer-physicist, senior research scientist and lecturer; former director of the EPFL Post-graduate Course in Energy; former vice-president of the Mars Society Switzerland.