ExoHab Phase 0: 2 pilots [June-Dec 08]
B.H. Foing et al

1. ExoGeoLab [Pilot 1]

(payload technology, science and robotics):
Field test w/ telescopes & environment station
Surface instruments (geophysical, geochemical and astrobiological)
Demo of tele-operations.

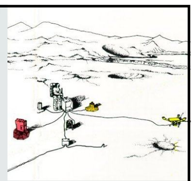
2. Habitat Lab [Pilot 2]

(human spaceflight and surface operations) :
Habitat for 4 "crew" with support facilities and life-support system units, demo of operations of instruments.

3. Design Support Office: [support function]

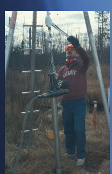
- Pre-Design Desk
- Support desk to definition of ESTEC 2 facilities
- Ground Control Desk for remote experiments
- Ground Control Desk for crew simulations
- Open user desk for demonstration and "marketing"

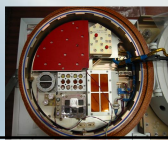
ExoGeoLab

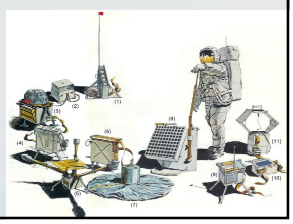


Field test for deployment of:

- **Surface instruments (from institutes)**
  - **Context geology, seismometer, radar**
  - **Weather /environment station**
  - **Geochemical package**
  - **Exo-biological analysis package**
- **Drill and subsurface sample collector**
- **Telescopes (solar and night instruments) and cameras already available**
- **Mobile robotics package**







Specific goals and experimental method: integrated ExoGeoLab

- **low mass imaging systems** from aerial view, panoramic context, 3D stereo, close-up and microscopic imaging,
- **atmospheric**, ionospheric, meteo, UV radiation, space weather monitors
- **geophysical** study of the surface and subsurface using seismometry
- **geochemistry** package to measure elemental and mineral composition from lander and rover
- **robotic mobility** with instrumented regional rover, mole, arm and local nanorover
- **sub-surface water and volatiles** detection and characterisation system
- **sample extraction, handling and analysis** systems

ExoGeoLab Pre-pilot phase 0 (May- Dec 08, ongoing)

- **Exo** pre-pilot installation of ExoGeoLab logistics and habitat lab (co- funded by D-TEC)
- installation of cameras, equipment and data handling
- research utilisation of instruments available
- adaptation of 3 telescopes (BHF research) equipped with cameras and filters (imaging of terrestrial scenes, the Moon, the Sun in H alpha , astronomical targets)

Sun in Hα

Moon-Earth tests

ExoGeoLab pilot phase 1A (Jan 09- Dec 09)

Procurement, adaptation and installation of commercial instruments:

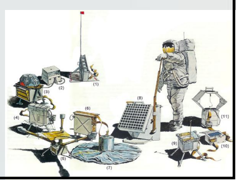
- CAM-0: cameras and new remote-controlled telescope for terrestrial/atmospheric, stars/ planetary real-time observations
- ROVER-0: support equipment on ExoGeoRover: comms, energy , pilot instruments
- PHYS-0: installation of geophysical observatory station: geophones, UV radiation, meteo monitors, permittivity probe, radio ionospheric sounder
- SUB-0: subsurface GPR radar
- CHEM-0: vis-IR spectrometer for organic and mineral analysis
- SAM-0: GCMS sample analysis (adaptation), sample handling, analysis systems, manual drill , organics and biological sensors
- GUEST: Accommodation of other guest opportunity instruments proposed by partners

Possible integration of instruments developed by partners or SRE-PA

- LMS-1: Laser Mass Spectrometer
- RAMAN-1: Mineral and organic diagnostics via Raman space breadboard
- ATR or QCM : detection of water layers at proximity of ice-dust mixtures

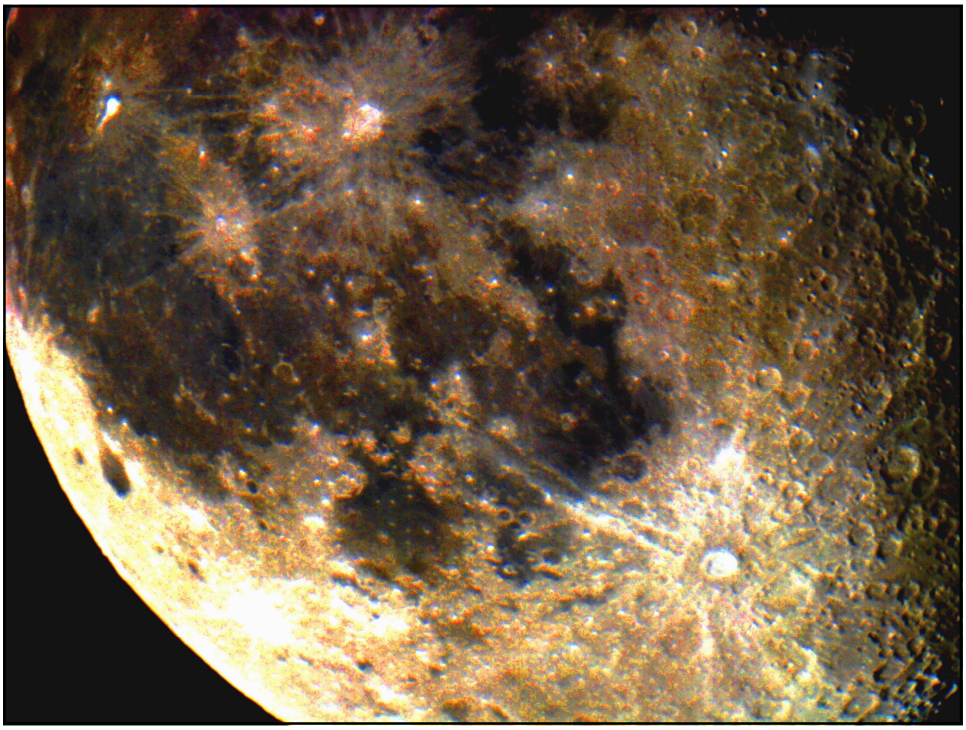
Field test of **subset** of instruments in a Mars Utah Desert research station (February 09)

Field test of **integrated package and instrumented rover** in OHP observatory (15-30 Jun 09)



Test of ExoGeoLab pilot telescopes

Support Habitat for Instruments Control
(co- funded by D-TEC)



Habitat Laboratory

Field test of:
- Habitat core for 4 "crew" operators
- Support units (added progressively)
  - Life support unit
  - Recycling
  - Resources utilisation
  - Energy system (solar cells /batteries),
  - Green house lab and food production
  - Lab racks (medical, life science, sample analysis ...)

Outputs:
- Demonstration of operations of instruments
  - Communication with ground control
  - ExoGeoLab research
  - Control of remote instruments (at partner institutes)
- Protocols and human performance assessment
  - Deployment of other mobile elements

Outputs:
  - Demo of surface research and tele-operation
  - Demo of man-machine interaction
  - Adaptation for field campaign or extreme environment

HabitatLab

HabitatLab

Lunar habitat and laboratory

Cramped internal environment

Agronomy building

-Life support

-Recycling

-Energy system

-Communication

-Resource utilisation

-Green house

-Food production

-Lab racks

medical

life science

sample analysis

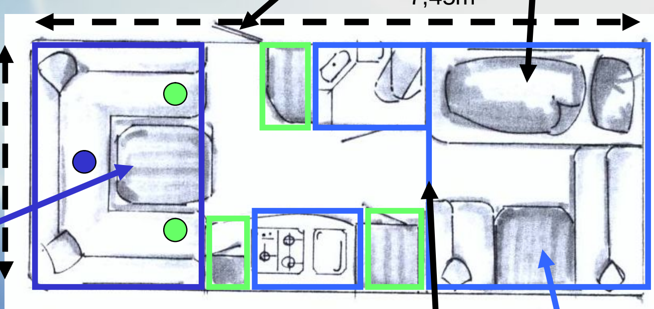
ExoGeoLab support:

-field campaign, mobility

-tele-operation

HabitatLab

Stern 530 K



test sites (field tests, lab - racks)

control centre (data analyses, reports, meeting)

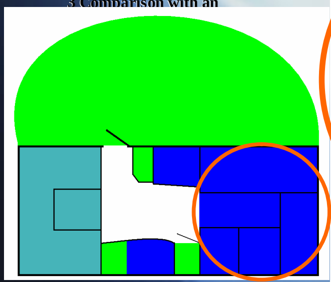
habitat part

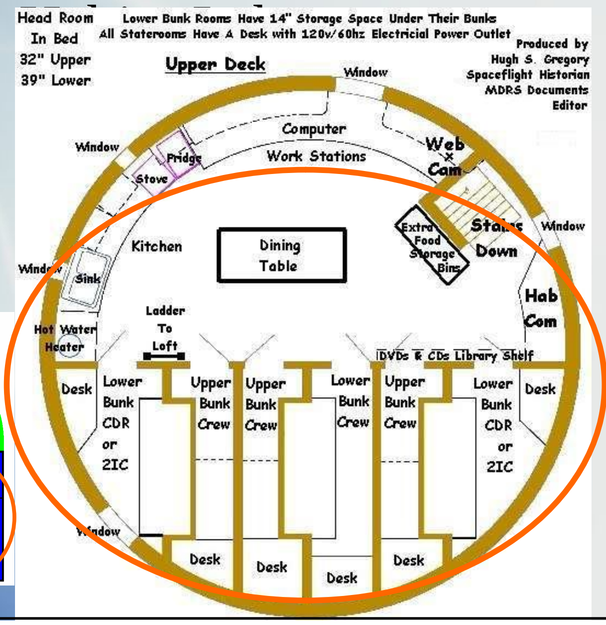
HabitatLab

test sites (field tests, lab - racks)
control centre (data analyses, reports, meeting)
habitat part

HabitatLab

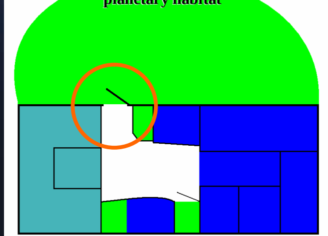
Mars Desert Research Station
Flashline Mars Arctic Research Station



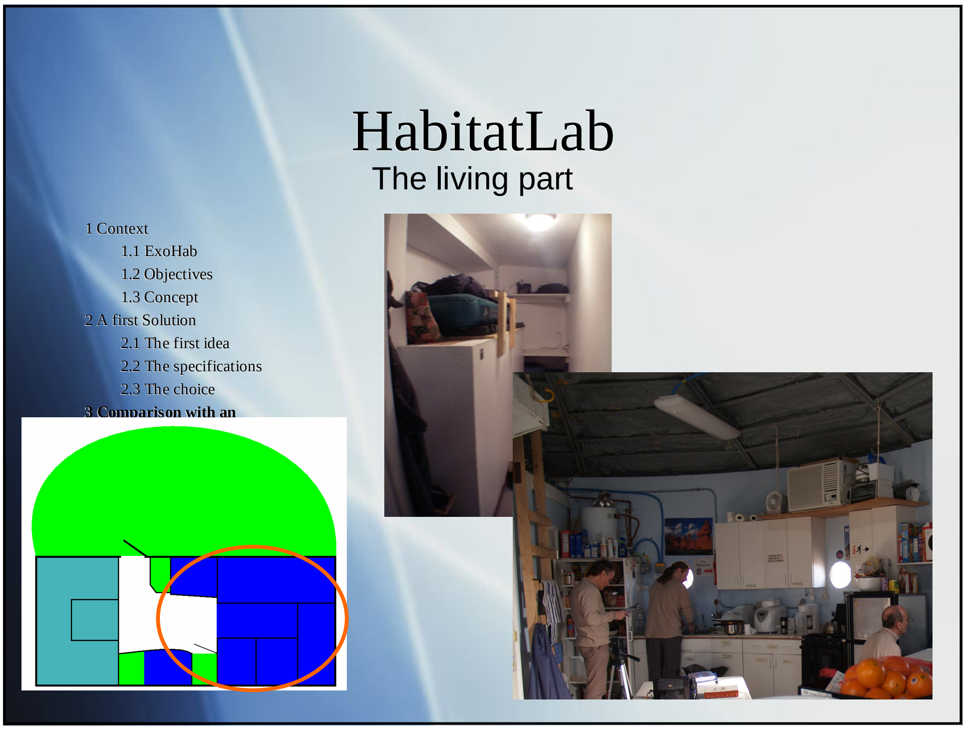


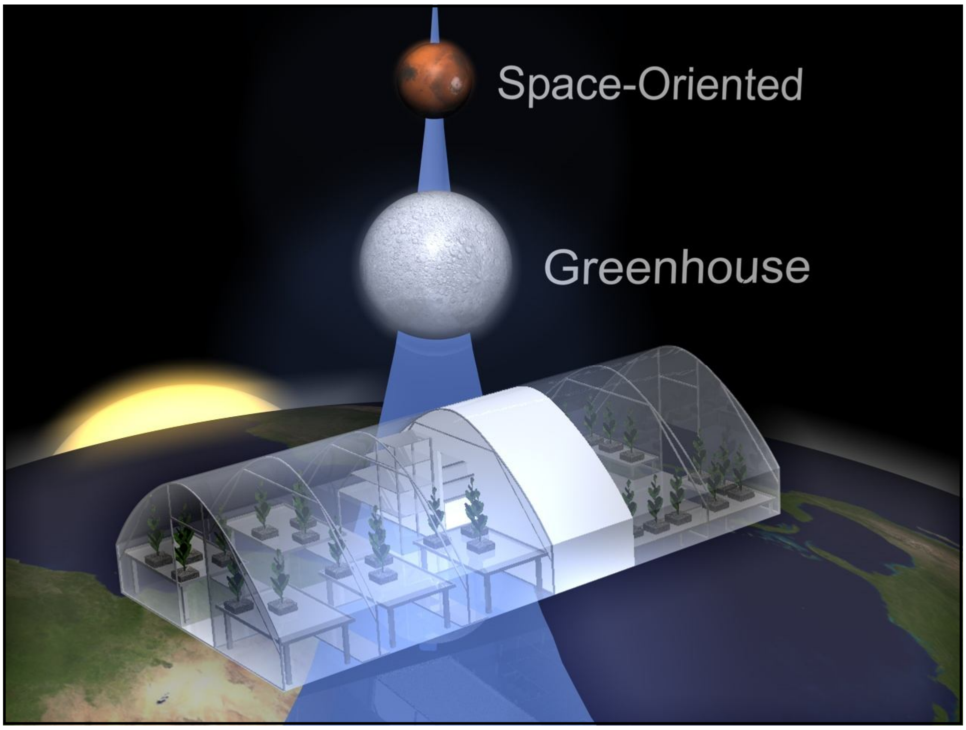
HabitatLab

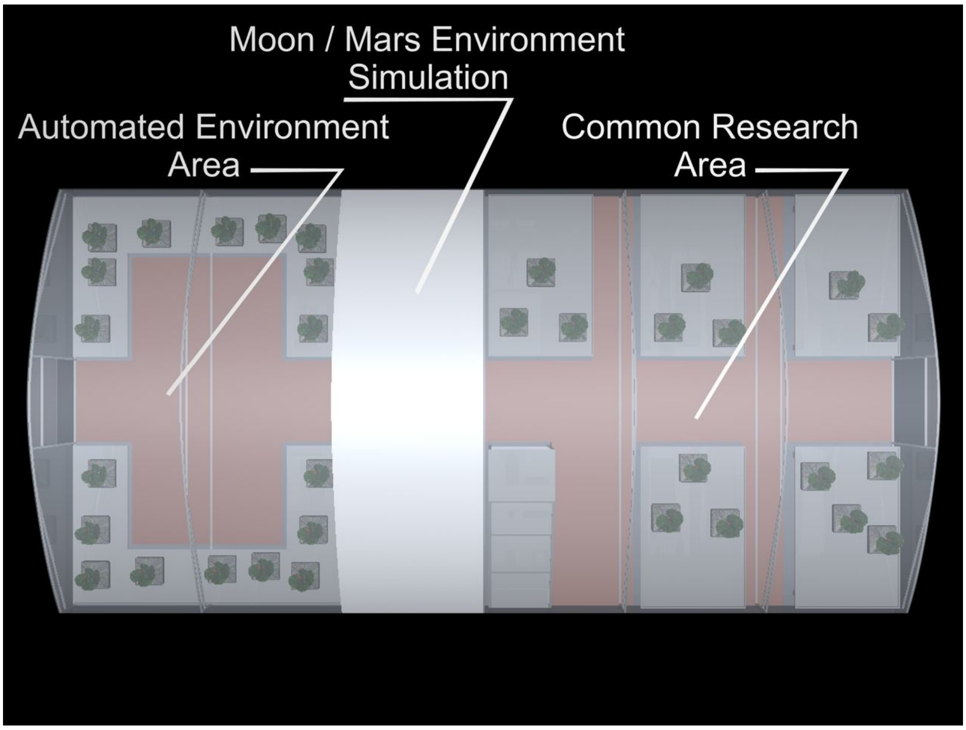
The entrance




HabitatLab
The laboratory - workshop
1 Context
1.1 ExoHab
1.2 Objectives
1.3 Concept
2 A first Solution
2.1 The first idea
2.2 The specifications
2.3 The choice
3 Comparison with an

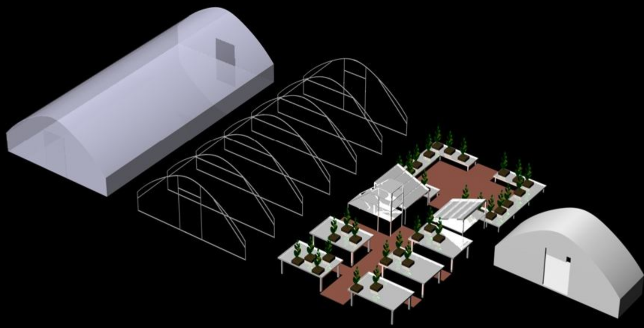

HabitatLab
The living part
1 Context
1.1 ExoHab
1.2 Objectives
1.3 Concept
2 A first Solution
2.1 The first idea
2.2 The specifications
2.3 The choice
3 Comparison with an


Space-Oriented
Greenhouse


Moon / Mars Environment
Simulation
Automated Environment
Area
Common Research
Area

Special plastic foil to control the sun light input parameters

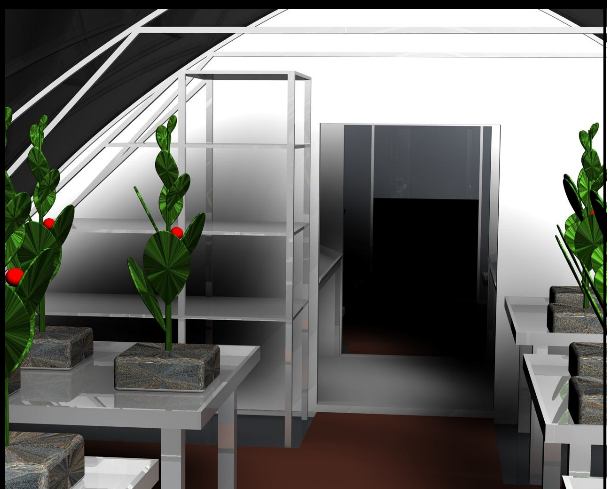
Lightweight structure for easy handle and assembly



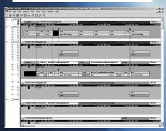
special equipment for each section of the greenhouse

Thermal isolation for moon and mars environment simulation

- Monitoring of environmental parameters
  - CO_2 concentration
  - O_2 concentration
  - Air / Ground Temperature
  - Air / Ground Humidity
  - Light intensity
  - UV intensity
  - Fire, toxicity



Support Design Office



- **Design Desk**
  - Support to definition of ESTEC 2 facilities
  - Pre-Design studies
  - Experiments definition and bread boarding
- **Ground control Desk**
  - for remote robotic experiments
  - for crew simulations and video conf.
- **Mapping and Navigation Desk**
  - Mapping, remote sensing, data and planning tools
  - Support to navigation and clean energy
- **Open users desk**
  - for demonstration
  - "marketing"

Short term Mid term 09

	Definition	Design for phase 1	Design for phase 2	
	DESIGN OFFICE			
CDF	Mini-CDF on laptop	Pilot pre-design studies	Design studies + breadboarding	
		Ground control experiments		
PSA, Geomatics	Mapping, data systems, Planning tools			
	GEO-PLANETARY LAB			
Instruments	Pilot lab	Geophysical lab facility	Exploitation	
Robotics lab	Hand-held drill	Robotic Drill		
	Manual sample	Robotic Sample collection		
	Sample analysis (minerals, organics)		New instruments/investigations	
	Astrobiology studies			
	Telescope	Remote operations		
	Context geological studies			
	HABITAT			
ISS, Columbus	Definition/procurement	Habitat crewed operations		
Melissa		Recycling		
		Water cycle	Atmospheric control	Closed loop
	Mini green house	Food production		
		Life science lab +racks	New instruments/investigations (racks)	
		Life-support		
	Crew communications			
		Inflatable structures		
	Batteries	solar pannels	Sustainable Energy	
			Resource utilisation	
	EARTH AND TECHNOLOGY APPLICATIONS			
Communications		In-situ validation of Earth observations		
		Sustainable energy		
		Miniaturization technology	Nanosat & microsat breadboard	

Community: WS1 COSPAR-LSI EPSC IAC WS2 ILC WS3

EXOHAB PLANNING 2008 PHASE 0

Funding sources

- D/TEC: habitat core + lab infrastructures+ equipment
- RSSD: research instruments, (2008, Proposal 2009-2011)
- GSP: study Techno Transfer sustainable habitat
- TRP Startiger: ExoHab proposal, integrated team 2009 A, resubmit end October
- Partners: researchers, students, instruments

GSP TECHNOLOGY TRANSFER FOR EXPLORATION & SUSTAINABLE HABITAT DEVELOPMENT

- B.H. Foing (SRE), M. Guglielmi (TEC), M. Freire
- WP0 Management, organisation of activities, requirements document, reporting, part time technical support (50 KEu)
- WP1 2 months CDF (75 KEu) Conceptual design for minimum Moon/Mars habitat (4 crew)
- - requirements for for minimum Moon/Mars habitat
- - functional and preliminary architecture analysis
- - identification and assessment of key subsystems (core habitat, energy, life support, resources, green house /food production, integrated instruments packages inside and outside habitat, communications, operations, crew mobility)
- - utilisation of modular cargo elements
- - evolution towards long duration and permanent base
- - Analysis of terrestrial applications and spin-off technologies
- WP2 2 month CDF (75 KEu) Conceptual Design for Habitat testbench
- - Definition of requirements for habitat testbed (in relation of WP1 minimum Moon/Mars habitat)
- - Preliminary architecture design
- - assessment of key demo subsystems for procurement (core habitat, energy, life support, resources, green house /food production, integrated instruments packages inside and outside habitat, communications, operations, crew mobility)
- - definition of scenarios for demo operations
- WP3 2 months (50 Keu) Habitat testbench Design validation test
- - Design validation Tests using ESTEC demo Phase 0 habitat (6 crew caravan procured Aug 08, and partly equipped)
- - Simulation and operations of activities
- - Verification campaign for design, operations, human/instruments protocol and planning tools
- WP4 3 months (2 contracts 50 kEu) Analysis and simulated operations of two critical technologies
- WP4.1- Design of test bench for habitat recycling (water, air, environment control, organics) and energy sustainability (collection, storage, conversion, utilisation, distribution)
- WP4.2- Design of distributed system package for habitat testbench support of human communications, EVA and mobility, power distribution, physiology/science/exploration/environment monitoring instruments,
- WP5 2 months (contract 50 kEu) ESA habitat testbed infrastructure and project planning
- WP5.1 - Definition and planning of technical infrastructure at ESA sites for habitat test bed development and operations,
- WP5.2 - preparation of field campaign activities in extreme and isolated terrestrial environment supporting Earth observation validation, regional geophysical research and human/robotic exploration simulation

Partners interest

- Dutch universities (contacts Phase 0)):

Delft U. (E. Gill/A. Noroozi et al , G. Drijkoningen, Hoekstra)

Vrij U. Amsterdam (G. Davies + collaborators)

Utrecht U./TNO (T. Zegers et al)

Leiden U. (P. Ehrenfreund et al)

SRON, NWO

+ (Phase 1) Dutch planetary forum, Dutch Space Leiden, Twente, Wageningen, etc..

- European: Liquifer Wien, Bristol U., Kent U., IPSL SA, ENSAM, Europlanet Network, U. of Wales (M. Grande), ISU
- + (Phase 1) DLR, Düsseldorf (JP de Vera), Duisburg- Essen, Open U., U. Leicester, SEEDS Torino Bremen, Supaero, RAL , SSC, Kiev, Florida Tech, NASA Ames

Short term plan 2008

- Ongoing Procurement:
- Equipment and support units in habitat
- Instruments on mid-size rover and station
- Communications/control systems
- Multi cameras and sensor systems

- Integration personnel and students from partners institutions
- Co-funding master/ PhD students (Delft, Amsterdam, U. Wales, ENSAM, Cranfield, ISU, SEEDS)

- Personnel
- Consolidate J. Page: few work days so far
- YGT request
- RF candidate
- Establish integrated team for january 2009

- Consolidate roadmap with programmes
  - TRP, GSP
  - Support ExoMars., link Moon-NEXT, Mars NEXT, Cosmic vision
  - Preparation for Techno demo lander mission
  - HSF habitat activities, European Moon-Mars station (1 M$)

Reserve slides

ESTEC Skunkworks Rationale & benefits B.H. Foing

- **Novelty:**
  - Total integrated engineering process ;
  - create a closed loop from design, feasibility, bread boarding and functional operation.
- **Added value:**
  - Reduced development time, costs, risks;
  - increased competitiveness; optimization
- **Technology and R&D support to ESA programmes**
- **Other benefits:**
  - Local and optional contributions by local authorities, MS and other partners

Manpower & Equipment need for Skunkwork at ESTEC

Skills & Manpower

1. **Permanent core team**
   - 1 skunkwork manager
   - 1 staff responsible CDF
   - 1 staff responsible for rapid prototyping/breadboarding
   - 1 system engineer
   - 1 logistic support
   - 1 administrative support
2. **Ad-hoc minipool team**

   4 to 6 people FTE with different expertise depending on needs

Equipment

- Multipurpose laboratories
- Concurrent Design and Bread boarding Facility (CDBF)
- Mobile Field Facilities (MFF)
- Multipurpose offices
- Social area

=> Complementary to ESTEC with extension of facilities accessible to partners

Phase 0 & 1- Internal & external support and users

Objective: Develop collaborative research

- **ESA/ESTEC Internal support identified:**

TEC M. Guglielmi, A. Tobias= Technology strategy

P. Perol, JL Gerner, M. Tossaint = certification of navigation, applications
C. Lasseur= Habitats and life-support for Aurora,
C.Paille= Green house and food production
G. Visentin: robotics aspects

RSSD B.H. Foing and researchers = supervision of research incubator definition, stagiaires and students, contacts with partners

ESI incubator: A. de Clercq, F. Salzberger, S. Davies

CDF M. Bandecchi= expertise and access to CDF tools

HSF S. Hovland= human systems and life support, link Aurora, surface ops.
M. Heppener= human physiology payload

EXR-EDU R. Walker: education hands-on projects

- **External SME partners**
  - E.g. NLR, Logica, Delft U. ,TomTom (navigation), MST Aerospace (clean energy), etc..

Why ESTEC skunks?

ESTEC skunks = ESTEC + integrated partners

- **Why close to ESTEC?**
  - ESTEC covers total engineering support from Design, R&D and Test.
  - ESTEC skunks builds on the expertise of ESTEC.
  - For better integration of partners (need for more flexibility).
  - Builds also on the potentials of the future space business park.

⇒ **Knowledge exchange** will be stimulated at the skunkwork thru collocated teams of research institutes, universities, industry and the support of ESTEC experts.

⇒ **“ Hands-on research”** will be enhanced with integrated design, workshop, training and interaction with the space business park (spin-off and spin-in).

Skunk works concept

- **Definition:** fast-track activities for problem solving, design studies from concept to rapid prototyping and bread boarding, advanced design training and light R&D in interaction with students, industries and academies.
- **Focus:** Integrated engineering process, optimization, partner integration and knowledge exchange in support of European Space activities
- **4 generic functions:**
  - *1- Design studies:* from concept to rapid prototyping
  - *2- Design training:* for students and industrials to new design processes/approaches
  - *3- Tiger team:* aggressive team of experts working non-stop on pb solving
  - *4- Light R&D:* support to ESA campaign, e.g. field campaign

Possible identified themes to start with:

- Design
- Science and robotics laboratory
- Human habitat
- Earth and Technology application demonstrations

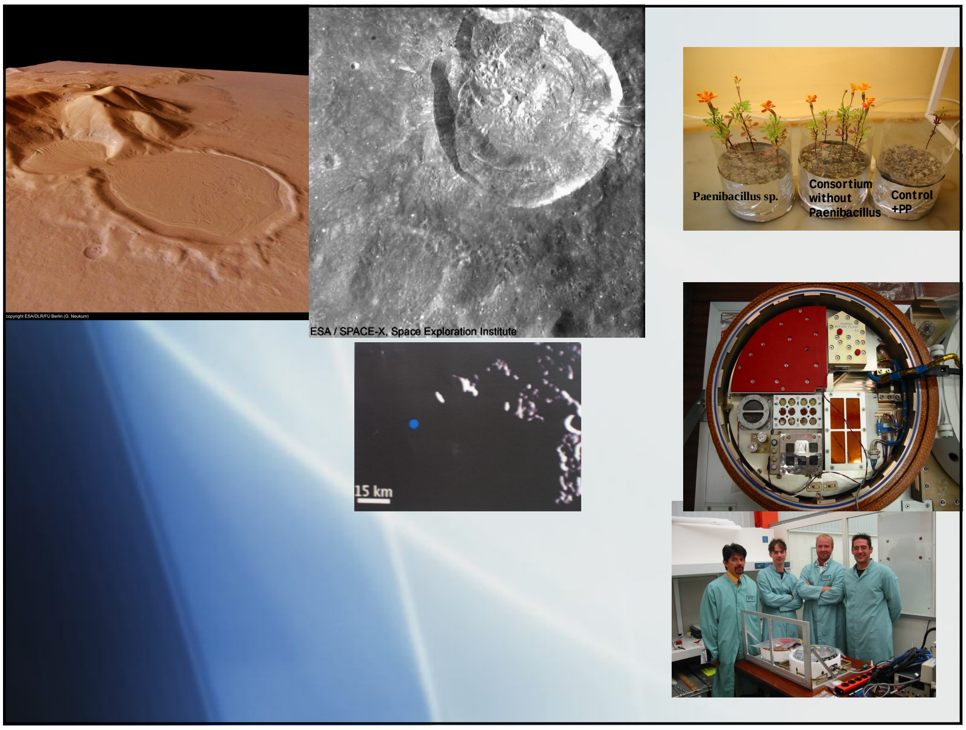
ExoGeoLab Lander and Rover Instruments: Demo &Research

RSSD research proposal

- **Lead Scientist:** B.H. Foing
- **Co-Investigators:** J.P. Lebreton (10%) , T. Zegers,
- Scientific advice: A. Chicarro, D. Koschny, J. Vago, H.Svedhem, M. Fridlund
- Technical collaboration: G. Visentin (TEC), M. Guglielmi, M. Freire (TEC), J. Page (TEC), R. Walker (LEX-EDU), M. Sabbatini (HSF-Erasmus)
- Students at ESTEC in 2009: S. Peters, E. Monaghan, L. Boche-Sauvan, R. Ernst, J. Oosthoek , P. Mahaputra, F. Rulli, P. Batenburg, A. Noroozi, & Delft rover design team

Data analysis, demonstration towards to future planetary landers

- To continue current data analysis and interpretation of remote sensing data (MEX, SMART-1, VEX, Cassini-Huygens) and in-situ (Huygens, MER) , and merging of multi-scale data sets
- Procurement and integration of geophysical, geochemical and astrobiological breadboard instruments in an surface station and rover (ExoGeoLab)
- Research operations and exploitation of ExoGeoLab test bench for various conceptual configurations (Moon, Mars, NEO, Titan)
- Contribution to the exploitation of surface lander results (MER, Phenix, MSL, preparation Exomars)
- Scientific simulation of planetary surfaces using laboratory and modelling tools
- Support research for definition and design of science surface packages on the Moon, Mars, NEO, Titan
- Research support to community preparation of payload for surface lander opportunities



Scientific background, rationale and specific goals

- Characterising samples in –situ
- Surface science for Mars, Moon, Titan or planetary missions
- From global mapping via specific studies of localised regions until microscopic scales
- Studies of rocks and soil in situ, or with sample return missions
- Systematic multi-instruments protocols, characterisation diagnostics,
- Merging of data from various techniques (photogeology and mineralogical wide scale mapping have been performed to some extent previously so significant new surface science results may only come from co-ordinated multi-instrument operations operating from the surface.
- Constraints on the environmental conditions (chemistry, mineralogy, and morphology) .
- **Moon laboratory for geophysics**
- **Mars various processes controlling the distribution history of water**
- Titan, validation of future compositional investigations of the solid surface or lakes, and their relation with the global atmospheric system.

methodic steps for research

- instruments to equip a **mid-size ExoGeoRover** (with ESTEC TEC robotics section), and a **small surface station**.
- payload (instruments, sensors, data handling) deployed, operated and used as collaborative **research pilot facility (ExoGeoLab)**
- **functional tests** and **correlated measurements**
- **remote control of instruments from an adjacent habitat** (ExoHab 6-crew caravan) and a remote science desk.
- **suite of measurements** : telescopic imaging reconnaissance and monitoring, geophysical studies, general geology and morphology context, geochemistry (minerals, volatiles, organics), subsurface probe, sample extraction and retrieval, sample analysis.
- **simulation of diverse soil and rocks conditions**
- **packages to characterise** geological context, soil and rock
- **Science investigations** : geology, geochemistry, penetration/survival of water, oxydant, organics, mineral and volatiles
- **facility for collaboration with partner**
- **field campaigns in specific locations**
- new **ability to cross-validate the techniques** and **enhance design and operations**, to exploit science in terrestrial environments, and build expertise for instruments development

Expected products and measure of excellence

- **Research and publications:** report and papers on concepts, methods, instruments, experimental results, science exploitation , research results from field campaigns at sites of geological interest (21 refereed papers and some 65 proceedings since 2005)
- **Hardware instruments products:** instruments demo suite
- **Software and operational tools benefits:** data handling, mapping, data merging, data analysis and planning surface instruments, remote control instruments operations

- **Previous related research:**
- Moon/Mars data analysis of SMART-1/Mars Express and other missions data
- production and analysis of samples for Interplanetary/space exposure (exposure of organics in space, Biopan2005, Expose –R 2008) & ground simulation
- exploitation of simulation chambers for Mars conditions (mineral and organic diagnostics)
- studies and characterisation of possible landing sites for Moon or Mars missions

- **Benefits to ESA space missions:**
- science and measurements preparation and validation for planetary lander missions (ExoMars, Cosmic Vision, Exploration Moon-Mars landers)
- merging between orbiter data and ground truth landers
- collaboration in science exploitation

- **Training of young researchers:** the ExogeoLab pilot facility is already being used with academic research collaborators

Benefit to community

- Feed back for definition, design, science operations and joint data analysis of surface packages of instruments for future Cosmic Vision studies or ESA Robotic Exploration (link ExoMars mission and Moon/Mars lander demos)
- **Previous collaborations and publications with external institutes:**
- Leiden U., DLR planetary institute and Free U. Berlin, VU Amsterdam, Utrecht Univ. , Delft U., IPG Paris, U Wales Kent University, Kiev U., Brown U. , NASA Ames, JPL, ASU, Florida Tech , GSFC
- Ongoing collaborations with ESTEC colleagues: ESTEC skunks pilot support, robotics section, Thermal Life support Div., ESA HSF human /machine performance, ESA education

Benefit to department(s), including cross-department/-discipline potential:

- ESA space science Cosmic Vision 2015-2025 , and new ESA exploration programme
- Moon, Mars, Titan, planetary Moons and solar system bodies.
- Accessible research facility and science environment for hands-on research for SRE scientists, in collaboration with other ESA researchers.
- It can be used from all RSSD sites via teleoperations and data analysis , and also for specific investigations campaigns in-situ.
- RSSD proposers : BHF developed ground work, and financial and administrative support from ESTEC and ESTEC skunks pilot project (+ integrated partners)
- Hands on research for study and project scientists,
- Synergies with ESAC planetary scientists, and SRE-PA

ExoGeoLab pilot phase 1 B (Jan- Dec 2010, 160 kEu)

- science exploitation of ExoGeoLab pilot by RSSD/ external partners
- procurement and installation of new instruments developed with partners, system test at ESTEC
- **Adaptation, material cost, installation, technical support for 7 partners equipments packages** (7x20 kEu)
- CAM-1: low mass imaging systems for panoramic context, highres imaging, and monitoring
- ROVER-1 upgrade of ExoGeoRover instrumentation package
- PHYS-1: geophysics package (seismometer, heat flow)
- CHEM-1: geochemistry package breadboard for small lunar and planetary landers
- SUBWATER-1: sub-surface water detection system: permittivity, radar
- DRILL-1: robotic drills (drill, mobile elements, analysis systems)
- BIO-1: organics and biological sensors package

- Arctic field test (Devon Island or Svalbard) with portable ExoGeoLab facility (20 kEu)

ExoGeoLab activities phase 2 (Jan 2011 – Dec 2011, 125 kEu)

Science exploitation autonomous portable ExoGeoLab facility : 20 kEu

Use as facility in ESTEC ; Use in Field tests with partners; Science validation and exploitation of techniques

Support to design enhancement and development of robust integrated breadboards (3x30 kEu):

- GEOPHYS-2: geophysics autonomous package heat flow, seismometers DLR Berlin/IPGP
- GEOCHEM-2: package application to small lunar and planetary landers
- ROVER- 2: breadboard rover with arm, mole and micro-instruments Delft TU/open U

Possible integration of additional instruments being developed by partners or SRE-PA (15 kEu)

neutron sensors: application to ice detection on Moon-Mars

low mass X-rays: X-ray fluorescence diagnostics of elemental composition

- **Possible follow up 2010+** (funded by community)**:** Development of surface instruments for lander opportunities

Manpower Resources

- B.H. Foing (30%, management, scientific supervision), technical support team
- **Co-Is:** J.P. Lebreton (instruments, 10%), T. Zegers (planetary GIS, 5 %), D. Koschny (consultant on cameras), J. Vago (link with ExoMars), A. Chicarro, H.Svedhem, M. Fridlund for the scientific exploitation
- **Students paid by partners:** candidates identified for 2009 (S. Peters, E. Monaghan, L. Boche-Sauvan, P. Batenburg, A. Losiak, P. Mahaputra), PhD students: R. Ernst, A. Noroozi, students Delft rover tests and design team, 20% at ESTEC.
- **Research fellows request** for 2009-2010: one RF to support operations and science exploitation
- **Computer support:** 1 instrument data handling engineer 25%, and data analysis tools and archives 50 %
- **Experts and consultants:**
- H/W development: experts included in lab equipment cost
- S/W development: planning tool, data merging, mini-CDF tool

- **SRE-PA support: Support on electronics and communication , automation/ telecontrol, U. Telljohann 25 %**
- Support on integration of instruments developed by PA 25%

- **D/TEC support:** Hands –on technical support for integration, workshop and tests, J. Page 25%, design support 25 % , lab support 25 % ,
- 20 K Eu support contracts for delivery and operations of equipment
- CAM-1, GEOPHYS, GEOCHEM-1, BIO-1, ROVER-1, SUBWATER-1, DRILL-1, DATA handling and fusion, mapping and geo-referencing, planning tools

- **Financial Resources (in Keuros)**
- **Contractors' missions: 20 kEu/yr**
- For 7 external instruments packages reps : 2 ESTEC meetings/ yr, 1 conf. / yr in Europe, 1 field campaign
- **Computer support:**
- S/W licences: IDL, ENVI, MatLab
- Computers (non ADM-I): 1 workstation, 3 robust laptops (instruments control/communications)
- **External purchases:**
- Laboratory equipment:
- Phase 1 A: Procurement, adaptation and installation of commercial instruments (see work plan)
- Phase 1 B: Adaptation, material cost, installation, technical support for 7 equipments packages from partners