Arthrospira-B
First photobioreactor for oxygen and edible biomass production in space

Dr. Ir. Natalie Leys

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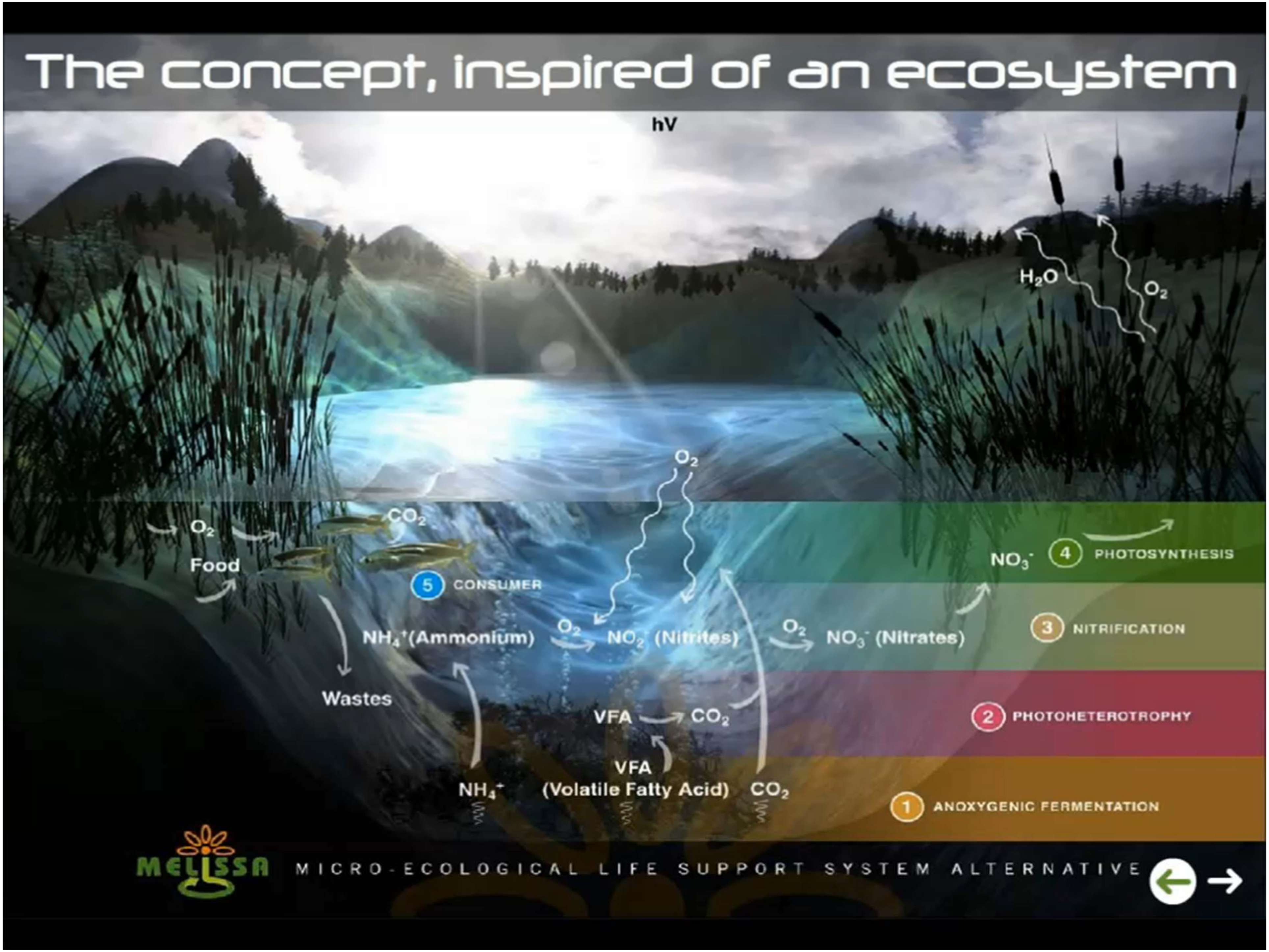
(2) (3) University of Mons UMons, Mons, Belgium; (4) University Clermont Auvergne UCA, Clermont-Ferrand, France;
(3) (5) European Space Agency ESA, Noordwijk, The Netherlands

Bio-based life support for human space exploration

- From the start of human space travel, research has been done to develop 'bioregenerative closed loop life support systems'
- especially for air revitalisation : CO_2 removal, and O_2 production
  → algae & cyanobacteria, for the photosynthesis process
- Examples from all over the world : https://en.wikipedia.org/wiki/MELiSSA
  - **BIOS** (1960's, IBP, **Russia**)
    – algae *Chlorella*
  - **MELiSSA** MicroEcological Life Support System Alternative (1987, **ESA, France & Belgium)**
    - cyanobacterium *(Nostoc) & Arthrospira*
  - **CELSS** Closed Ecological Life Support System (1989, **NASA**, US)
    - cyanobacterium *Arthrospira*
  - **CEBAS** Closed Equilibrated Biological Aquatic System - AQUARACK unit (1992, **DLR, Germany**)
    – algae *Chlamydomonas*
  - **CERAS** Closed Ecological Recirculating Aquaculture System (1997, **Japan**)
    - algae *Euglena* and *Chlorella* en cyanobacterium *Arthrospira*
  - **CAES** Closed Aquatic Ecosystem (2004, **China**)
    - algae *Chlorella*
  - …
- Currently 'Research and Development' on Earth, no system "in use" in space


SCK•CEN
founding member of
MELiSSA
Since 1989
Prof. Dr. Max Mergeay
(SCK•CEN)
1 of the 4 'fathers' of MELiSSA
Director of MELiSSA Foundation
www.melissafoundation.org
MELiSSA FOUNDATION
SCK•CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE


The concept, inspired of an ecosystem
hV
H_2O
O_2
O_2
O_2
CO_2
Food
5 CONSUMER
NO_3^-
4 PHOTOSYNTHESIS
NH_4^+(Ammonium)
O_2
NO_2^- (Nitrites)
O_2
NO_3^- (Nitrates)
3 NITRIFICATION
Wastes
VFA
CO_2
2 PHOTOHETEROTROPHY
NH_4^+
VFA (Volatile Fatty Acid)
CO_2
1 ANOXYGENIC FERMENTATION
MELiSSA
MICRO-ECOLOGICAL LIFE SUPPORT SYSTEM ALTERNATIVE

The challenges are big

Dissecting the earth ecosystem to its essential components & understand how they work

Then putting them back together, but smaller, with less complexity, less buffers or back-ups, …

Nevertheless predictable & reliable
Engineered to targeting maximum yield

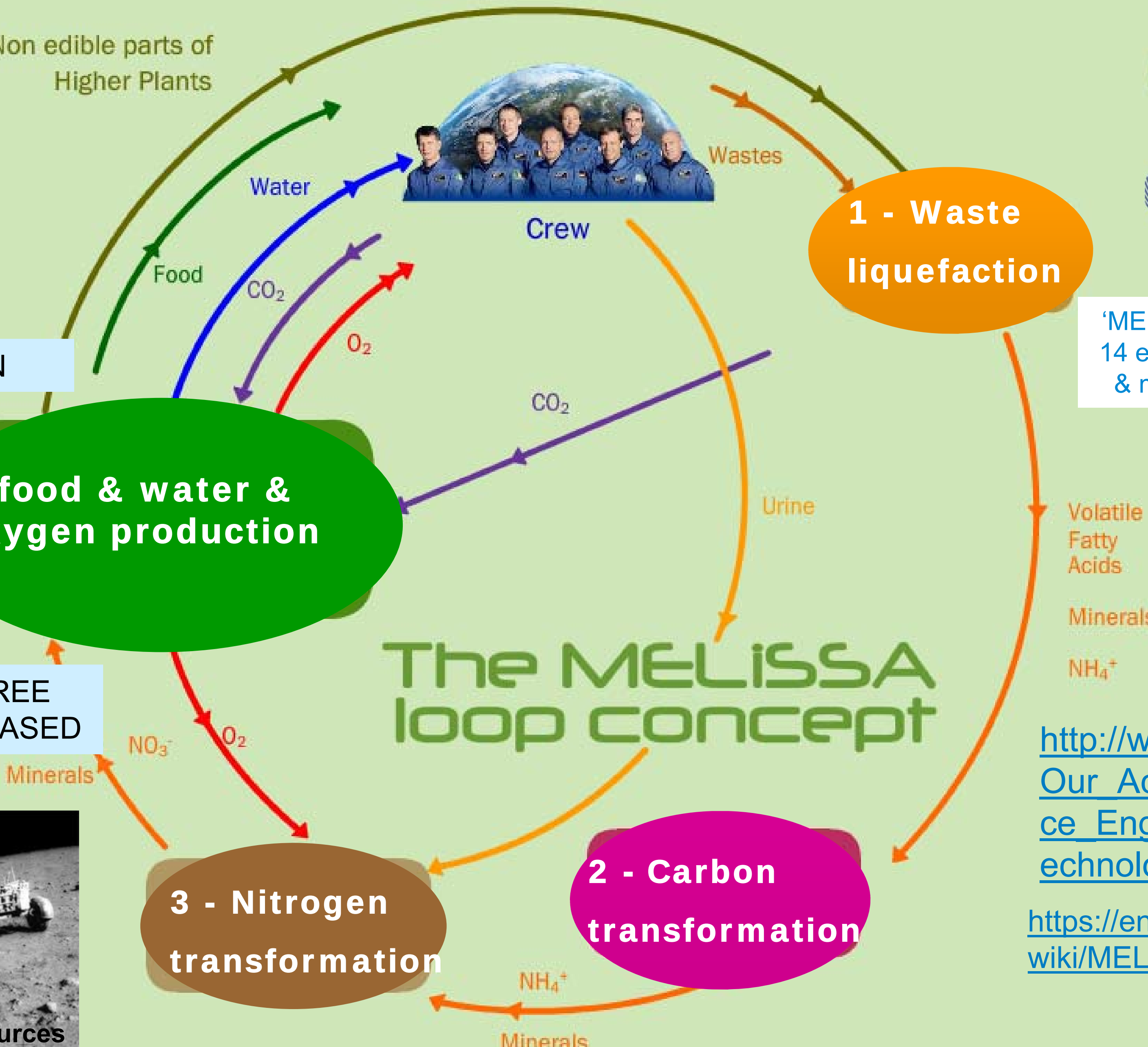
Using biotechnology which can be functional in space conditions (launch & radiation & microgravity)

A mineaturised sustainable
synthetic earth ecosystem
transplantable to space

30 years of MELiSSA …

MELiSSA team at work

MELiSSA team … after work



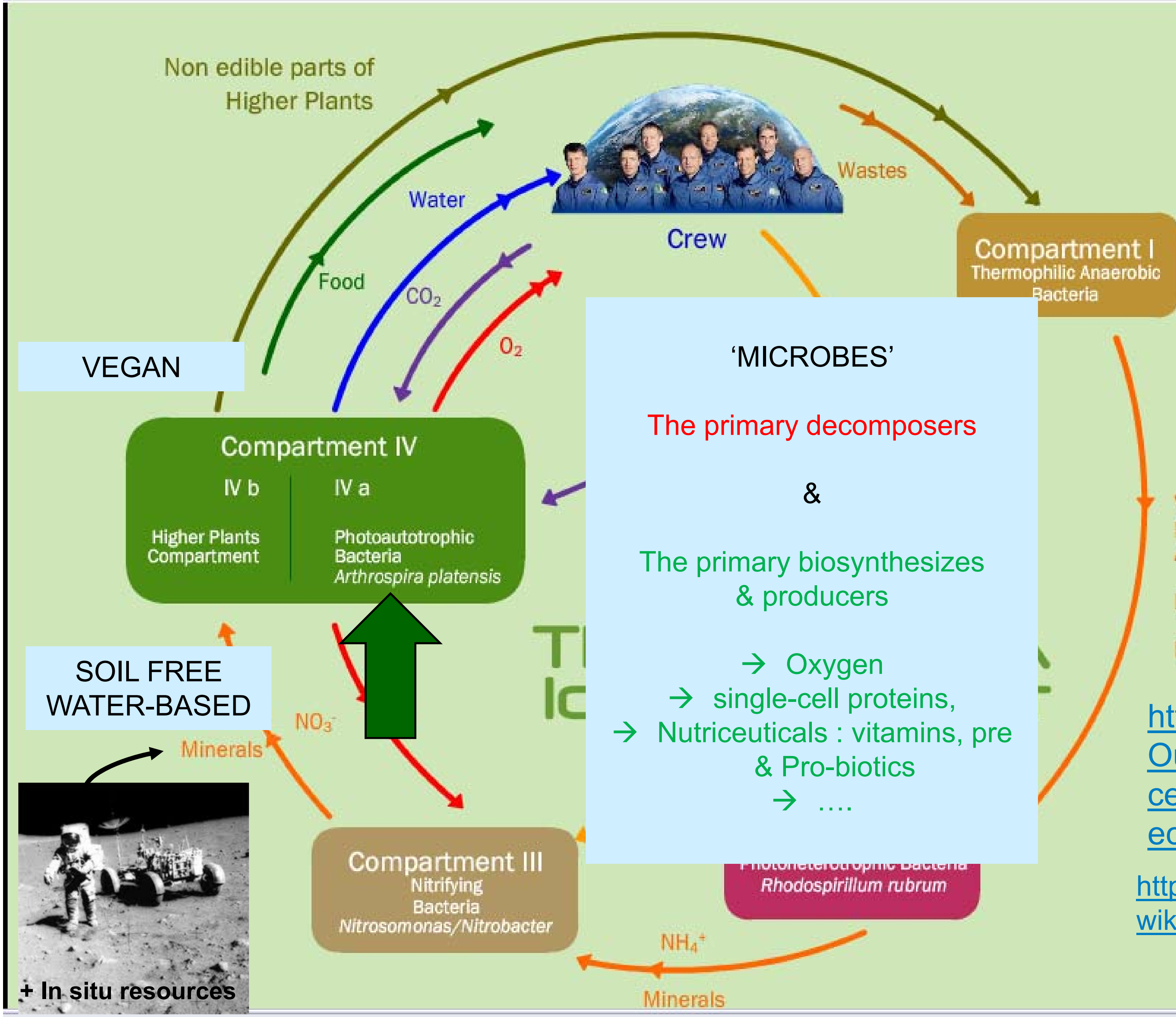
VEGAN

SOIL FREE
WATER-BASED

'MELISSA community'
14 european Members
& many contributors

http://www.esa.int/Our_Activities/Space_Engineering_Technology/Melissa

https://en.wikipedia.org/wiki/MELiSSA



VEGAN

SOIL FREE
WATER-BASED

'MICROBES'

The primary decomposers

&

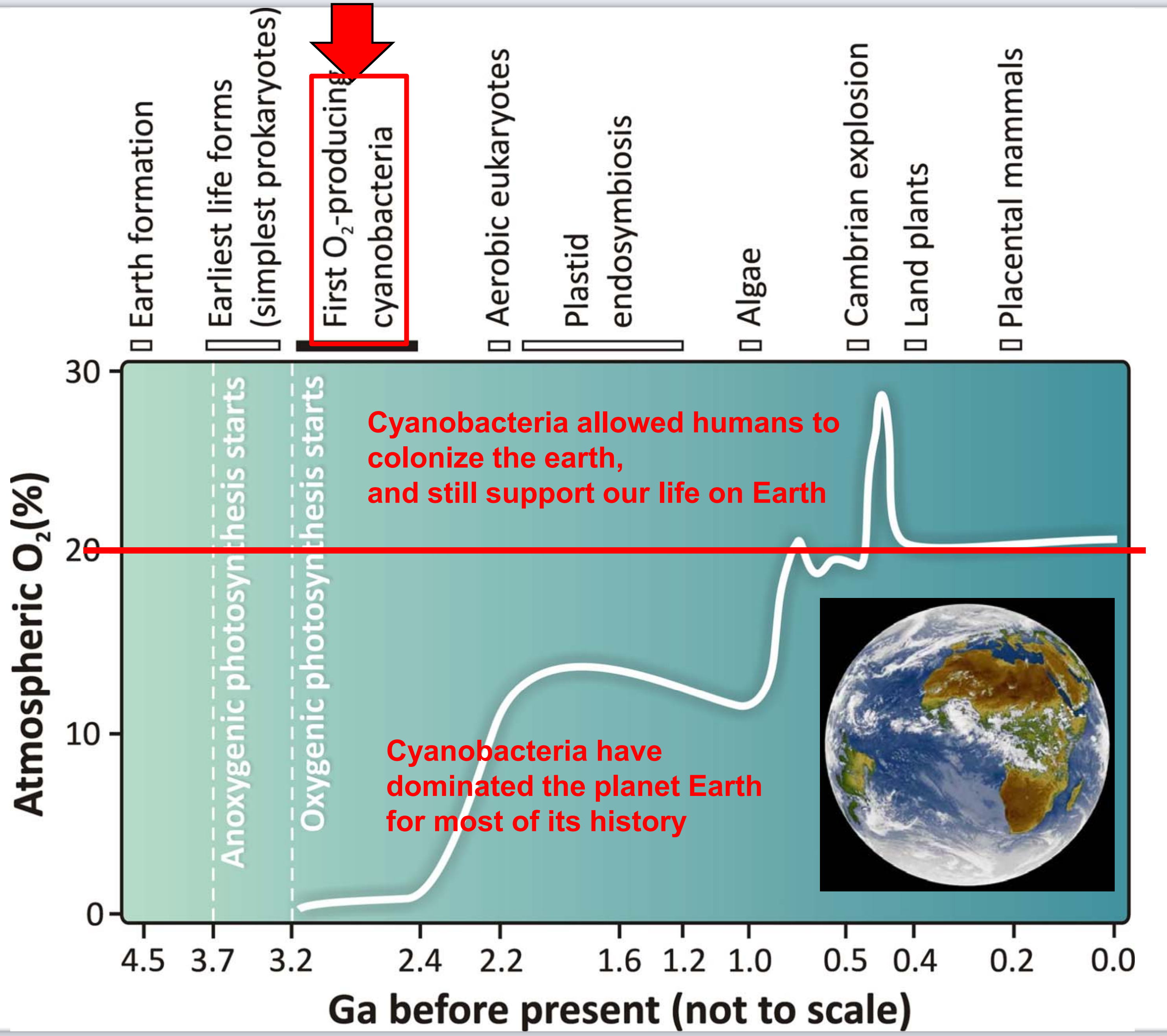
The primary biosynthesizes
& producers

→ Oxygen
→ single-cell proteins,
→ Nutriceuticals : vitamins, pre
& Pro-biotics
→ ….

'MELISSA community'
14 european Members
& many contributors

http://www.esa.int/Our_Activities/Space_Engineering_Technology/Melissa

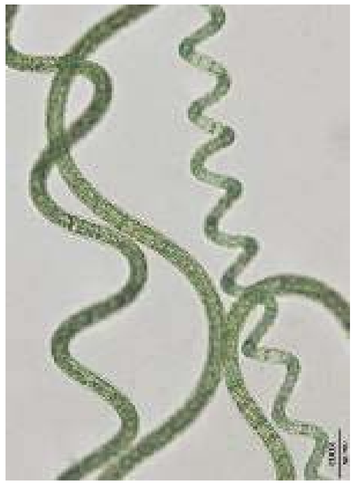
https://en.wikipedia.org/wiki/MELiSSA

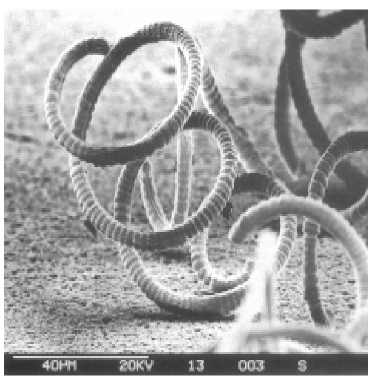


Earth IS a closed life support system

Oxygen production in space with cyanobacteria

Arthrospira





6 µm x 400 µm

- Blue-green filamentous cyanobacteria
- Lives in warm alkaline salty lake water, water rich in carbonates, at pH 9 & 35°C
- Cylindrical cells, in helicoidale strings, called ‘trichomes’ or filaments

- Continuous illumination, no need for dark
- Very high photosynthetic efficiency
- High cell density Bioreactor cultivation

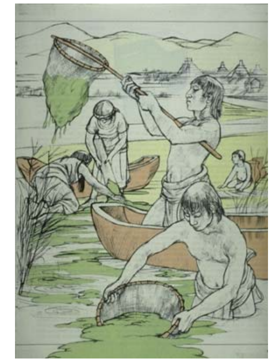
- Also known as Spirulina food supplement

In SPACE - life support system - MELiSSA

PHOTOSYNTHESIS for
- CO_2 removal from the air
- O_2 Production of from water,
- Nitrogen from waste water into proteins
- Edible biomass production

Arthrospira – food supplement

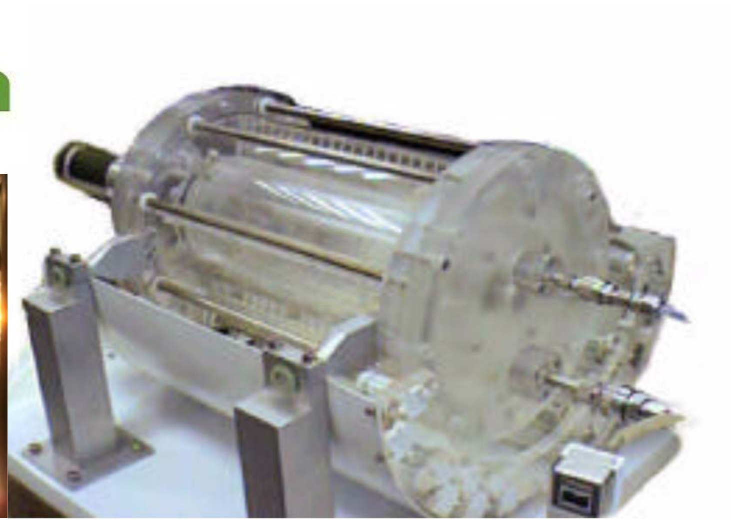
- Edible
  - Consumption by Aztecs, documented since 1500
  - Still used by several tribes in Africa
  - In Europe/Asia known as ‘super food’ – Spirulina



- Highly interesting Food value
  - thin cell wall, full organism digestible, no need for processing or cooking, no waste (↔ algae, plant)
  - Single cell protein source, Low DNA/protein-content (↔ other bacteria, algae, plant)
  - Does not contain phyco-toxines (↔ other cyano)
  - Rich in essential fatty acids
  - Contains vitamins, minerals, antioxidants, immunomodulators, prebiotic, …

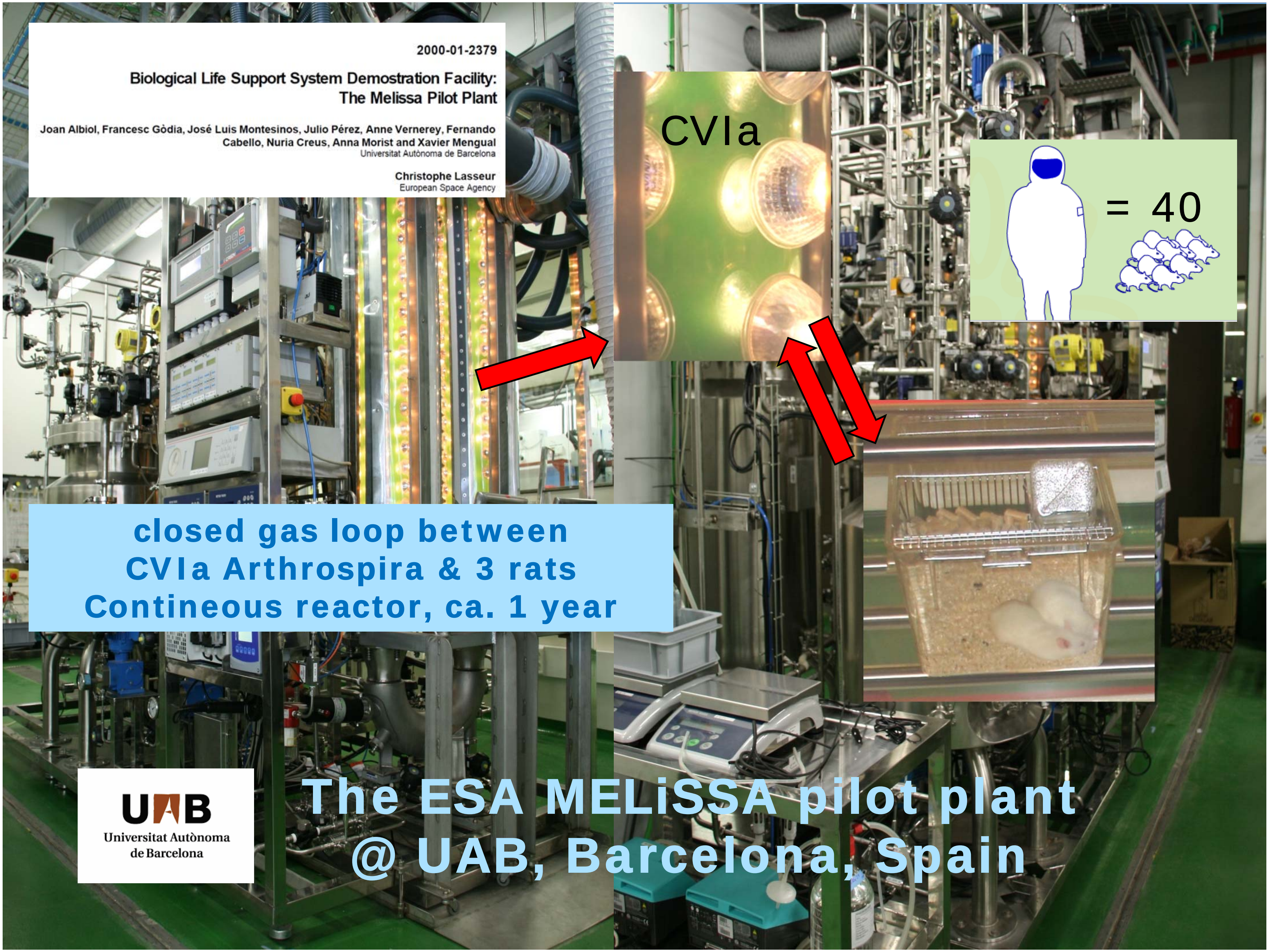
Bio-engineering – *Arthrospira* in photo-bioreactor

Arthrospira is an efficient oxygen producer e.g. BIORAT experiment


- The rat consumes O_2 and produces CO_2; the bacterium produce O_2 and consume CO_2 with light energy input
- the photosynthetic yield (O_2/CO_2) of the algae matches the respiratory quotient of the rodent (CO_2/O_2); by playing on light energy supply & predictive model
- A ground demonstrator has validated the concept : 2-months experiment

DEMEY D. *et al*. 2000 "BIORAT : preliminary evaluation of biological life support in space environment developments". SAE paper 2384, 30th International Conference on Environmental Systems, Toulouse, France July 10-13th, 2000.


2000-01-2379
Biological Life Support System Demostration Facility:
The Melissa Pilot Plant
Joan Albiol, Francesc Gòdia, José Luis Montesinos, Julio Pérez, Anne Vernerey, Fernando Cabello, Nuria Creus, Anna Morist and Xavier Mengual
Universitat Autònoma de Barcelona
Christophe Lasseur
European Space Agency
CVIa
= 40
closed gas loop between
CVIa Arthrospira & 3 rats
Contineous reactor, ca. 1 year
UAB
Universitat Autònoma de Barcelona
The ESA MELiSSA pilot plant
@ UAB, Barcelona, Spain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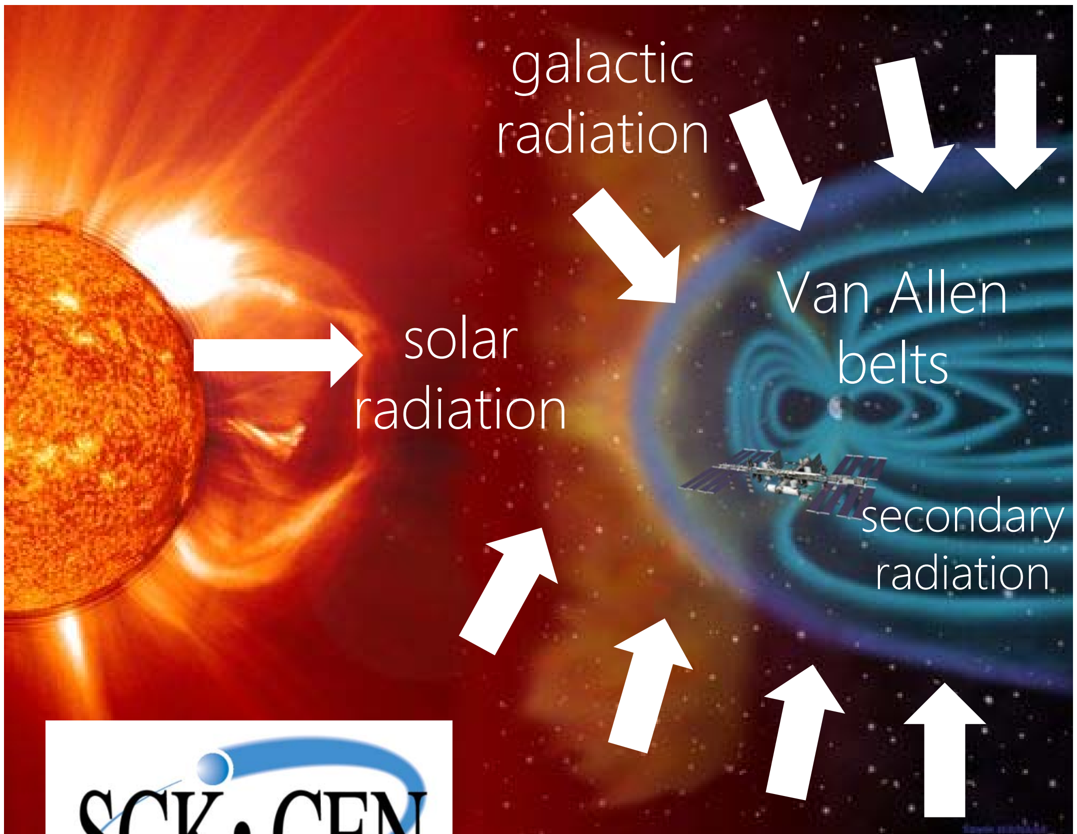
european astronaut centre
esa
Does this also work in space ?

Cosmic radiation in space → Biological impact ?



Dose rates in space higher than on earth

- On Earth ~ 0.1 µSv/h
- On ISS (LEO) ~ 25 µSv/h
- On the way to mars ~ 75 µSv/h
- On surface of mars ~ 25 µSv/h

x250

⇒ Necessary to monitor radiation doses in space

Type of Radiation in space different then on earth

- Electrons, protons, helium nuclei, heavier nuclei, neutrons, photons, muons, pions, …
- Up to extremely high energies around 10^{12} MeV
- Strong dependence on location, solar cycle and shielding

⇒ Very challenging to assess radiation doses in space

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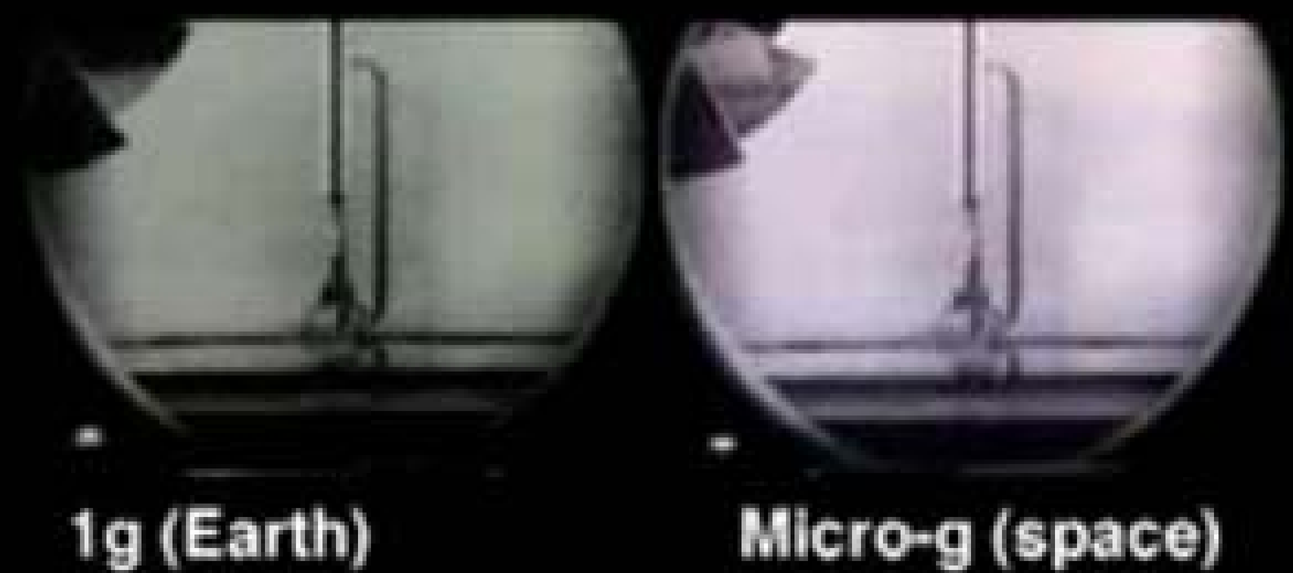
Reduced/Altered gravity in space → Biological impact ?

Earth	Space
Sedimentation, Convection, Diffusion	Diffusion only → Fluid quiescence, 'low shear'



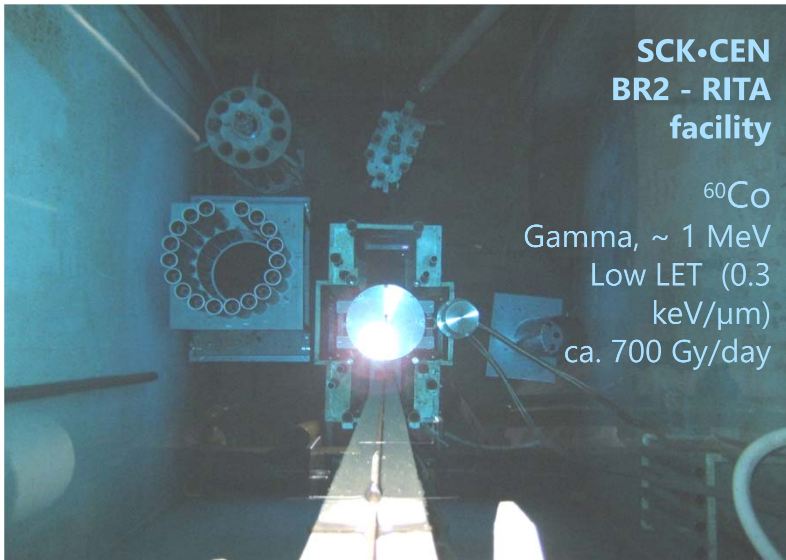
e.g. boiling water in space

different solid/liquid/gas fluid dynamics

& separation

Testing impact of space conditions… on Earth

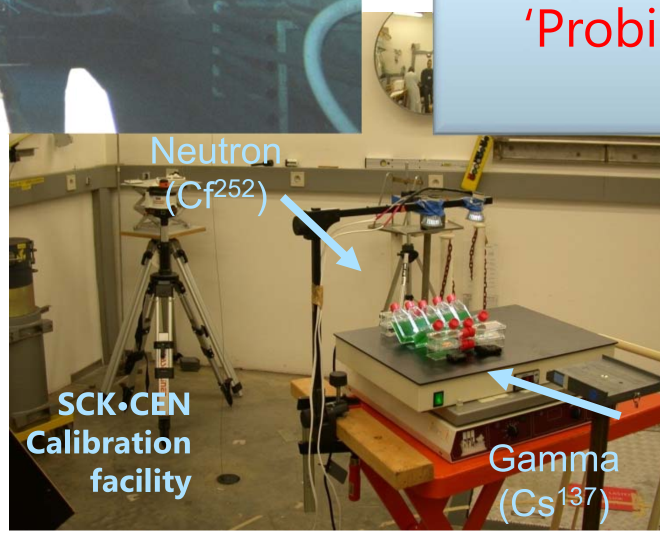
Simulation of space radiation and low gravity on earth ….



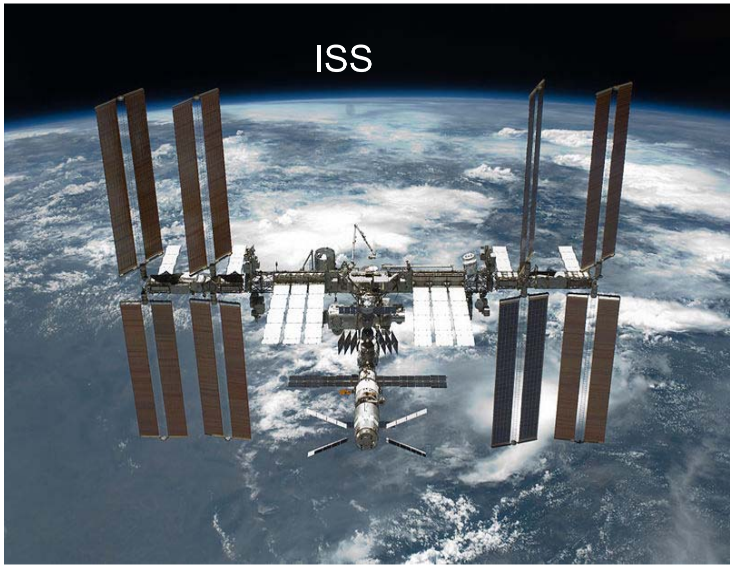
Reduced gravity simulation

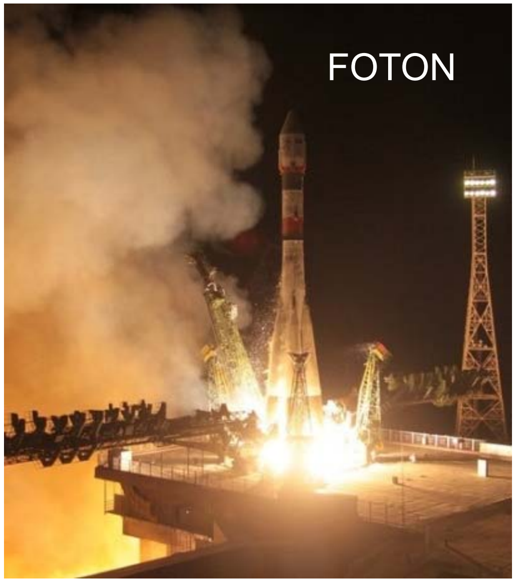
Presentation
Guliana Senatore (UNapoli)
'Probiotic Lactobacillus under SµG'

Cosmic Radiation simulation



Testing impact of space conditions… in LEO



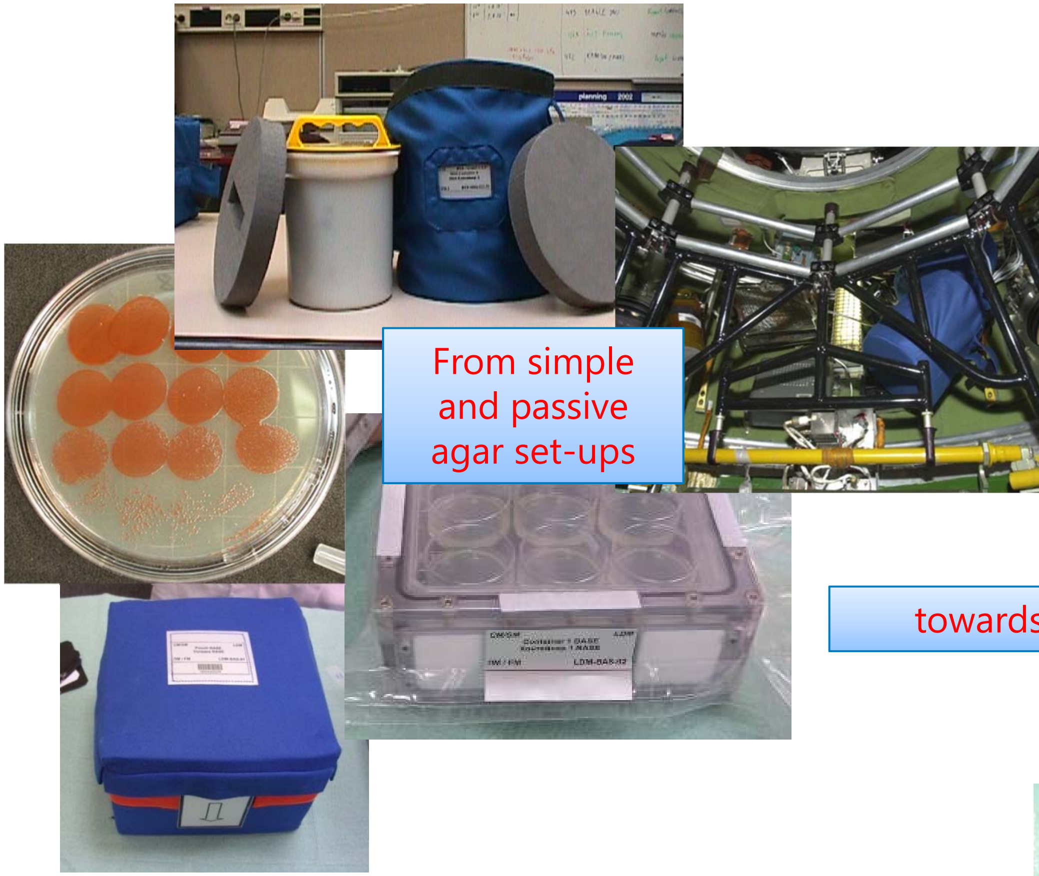


Parameters	Earth	LEO (~4*10² km dist.) ISS	Interplanetary Space (>7*10⁴ km dist.)	Moon (4*10⁵ km dist.)	Mars (4*10⁸ km dist.)
Ionizing radiations (µGy/day)	2-4	160-500[a]	220-1270	~ 400	200-300 (max.20,000)
Gravity (g)	1	10^{-6} – 10^{-3}	< 10^{-6}	~ 0.2	~ 0.4

LEO: low Earth orbit, **Dist**.: distance from the Earth, **a**: inside space station

Learning curve
Testing how MELiSSA bacteria survive and grow in space

- **MESSAGE 1** October 2002
- **MESSAGE 2** October 2003
- **BASE A** October 2006
- **Mobilisatsia** April 2007
- **BASE B& C** October 2008
- **Nitrimel** July 2014
- **BiSTRO** August 2015
- **Artrospira-B** December 2017



From simple and passive agar set-ups

towards

more complex and active liquid systems

Bibliography @
http://www.melissafoundation.org/

Impact of space flight on microbial cells

Reduced Gravity

- Stationary fluids around the cells (low fluid shear)
- Accumulation of waste products around the cells (only diffusion, no convection)
- Lower mechanical forces
- Decreased nutrient supply (only diffusion)

Will the bioprocesses be the same in space ?

other factors

- ...
- No movement due to gravity or magnetism (taxis)
- Altered day-night rhythm

Increased Radiation

- ROS in the medium and cells due to radiation (radiolysis)
- Damage to DNA, proteins and membranes due to radiation
- Higher doses of UV

Impact of space flight on microbial cells

Reaction strongly depends on the growth conditions and bacterial strain used

- **Increased growth rate and higher final biomass production**
- **'starvation' reaction activated**
- **Changes in metabolism**
- **Increased production of secondary metabolites**
- **Altered cell-cell communication**
- **Increased resistance to biocides (antibiotica, alcohol, acid, oxidants, etc.)**
- **Stress reaction system activated**
- **Increase virulence**
- **…**

Effect of microgravity & space radiation on microbes

10.2217/fmb-2017-0251 © 2018 Future Medicine Ltd   *Future Microbiol.* (Epub ahead of print)

Giuliana Senatore[1], Felice Mastroleo[2], Natalie Leys[2] & Gianluigi Mauriello*,[1]
[1]Department of Agricultural Sciences, University of Naples Federico II, 80055 Portici, Naples, Italy
[2]Microbiology Unit, Belgian Nuclear Research Centre (SCK•CEN), 2400 Mol, Belgium
*Author for correspondence: giamauri@unina.it

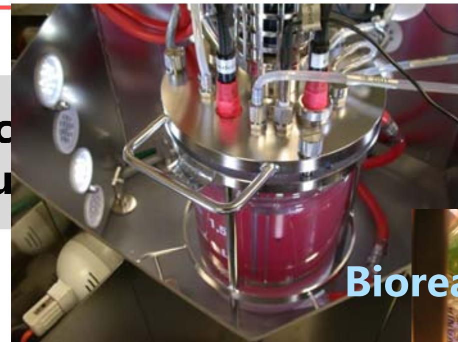
Bibliography @ http://www.melissafoundation.org/

Anticipating the impact of spaceflight

Gravity

Fluid quiensceno
the cells (low flu

Lower mechanical forces



Process engineering

:cumulation of
ounds around cell
diffusion only)

Reduced nutrient supply (by diffusion only)

…

No gravity or magnetic based taxis

Ar
illur

Different day-n
cycle

Other

n

ROS in medium and cells produced by ionising radiation (hydrolysis)

onising radiation causing
, protein and lipid damage

JV

Radiation

Arthrospira Gene
Expression study and mathematical
Modelling on cultures grown in the
International
Space
Station

L. Hendrickx, 2004

ArtEMISS project

"First bioreactor with cyanobacteria in space"

For controlled microbial oxygen and food production in space

- Investigating
  - Oxygen production
  - Biomass production
  - Biomass Biochemical composition (nutritive value)
- In a controlled photo-bioreactor,
  - axenic (1 strain),
  - batch & continuous,
  - defined continuous illumination (no day/night),
  - Fixed temperature and
  - synthetic waste water
- Under spaceflight conditions : gravity, radiation, magnetism …

Bio-engineering – *Arthrospira* in mini photo-bioreactor

UNIVERSITÉ Clermont Auvergne

Biotechnol. Prog. 2005, 21, 741–750 741

Design, Operation, and Modeling of a Membrane Photobioreactor to Study the Growth of the Cyanobacterium *Arthrospira platensis* in Space Conditions

Guillaume Cogne,* Jean-François Cornet, and Jean-Bernard Gros

Laboratoire de Génie Chimique et Biochimique, Université Blaise Pascal, CUST, 24 avenue des Landais, BP 206, 63174 Aubière - Cedex, France

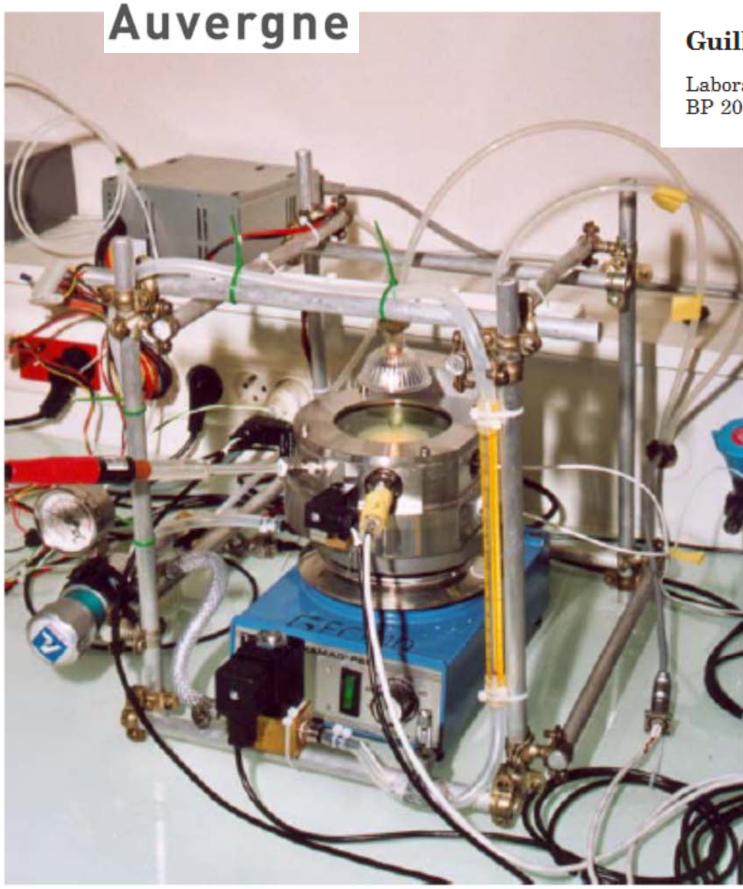


Figure 5.3 : Photographie du réacteur.

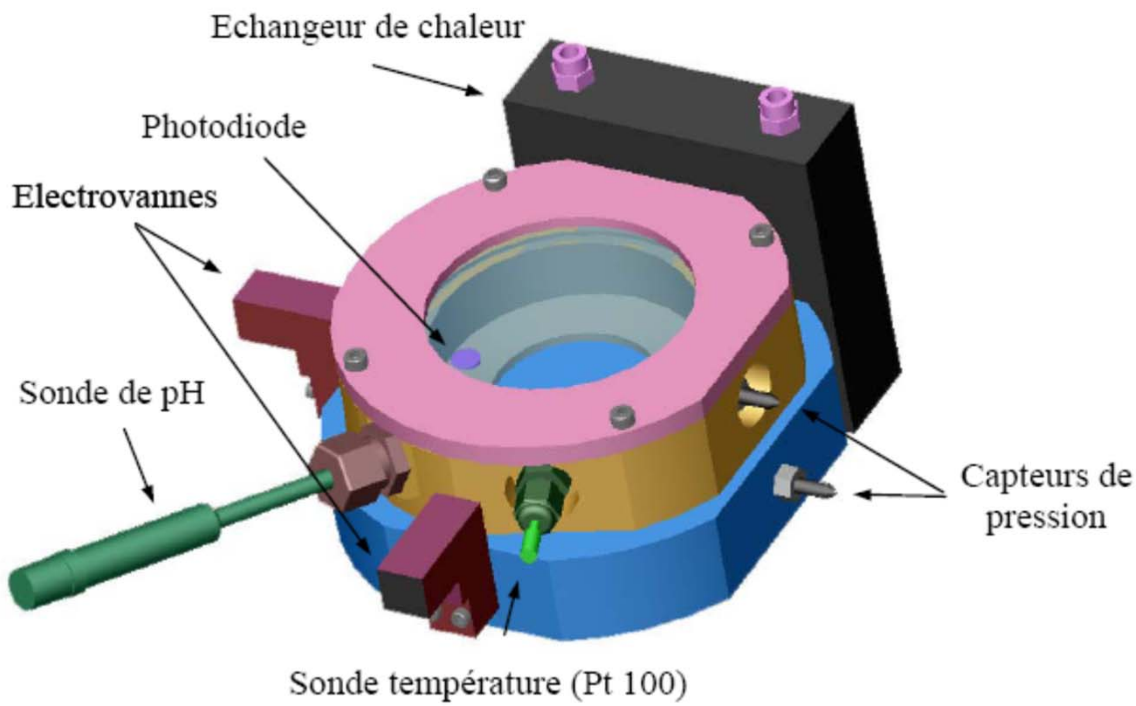
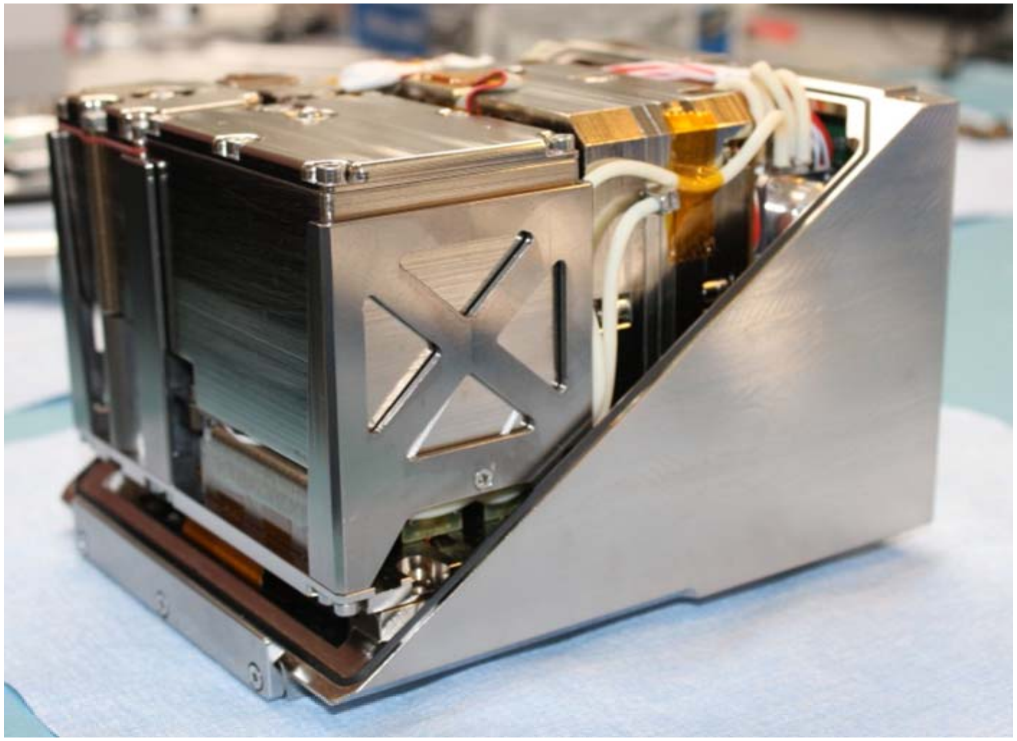


Figure 5.2 : Schéma du réacteur.

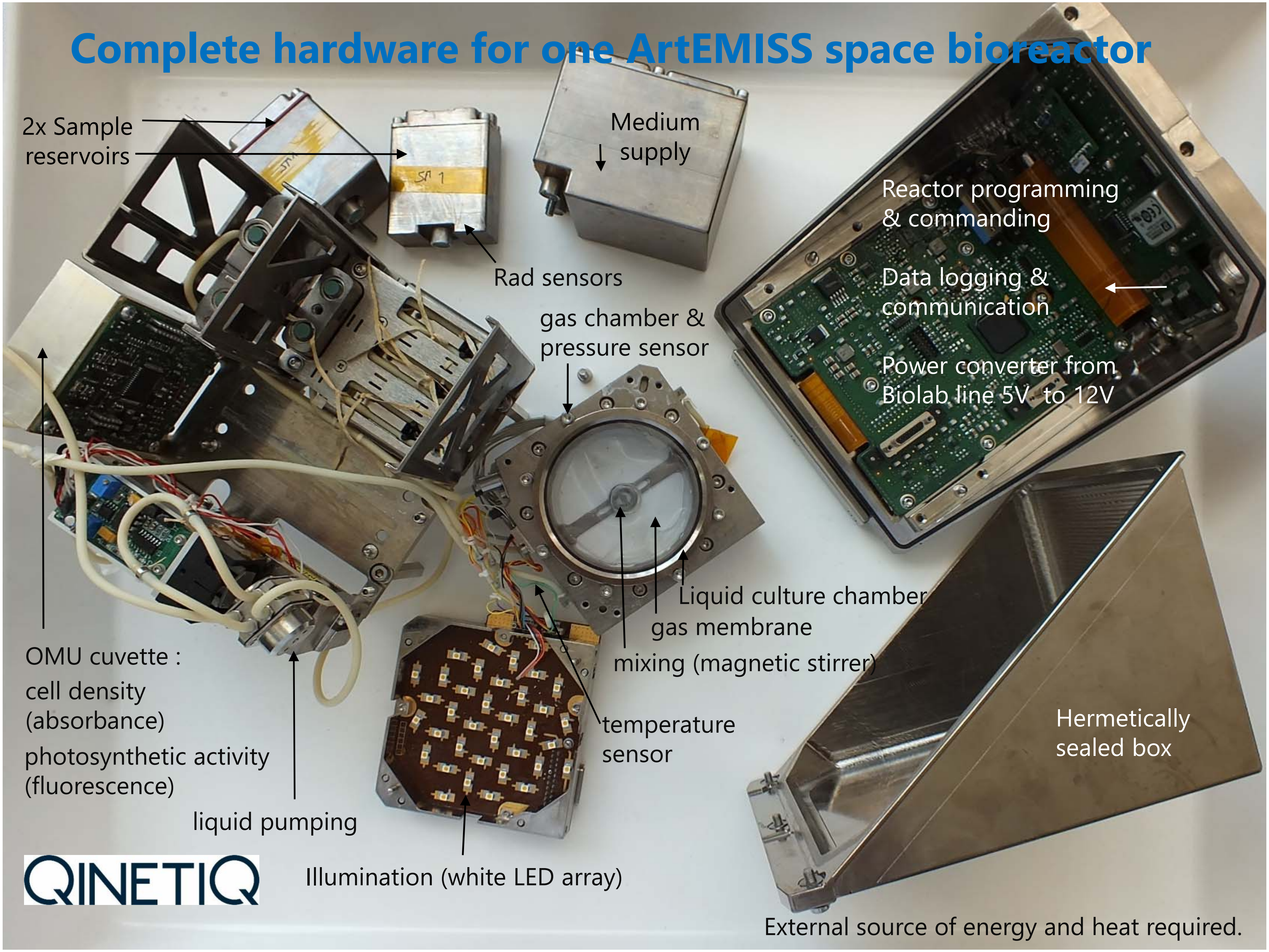
ArtEMISS Space photobioreactor

QINETIQ



Portable miniaturized
photo-bioreactor
(50ml liquid volume)

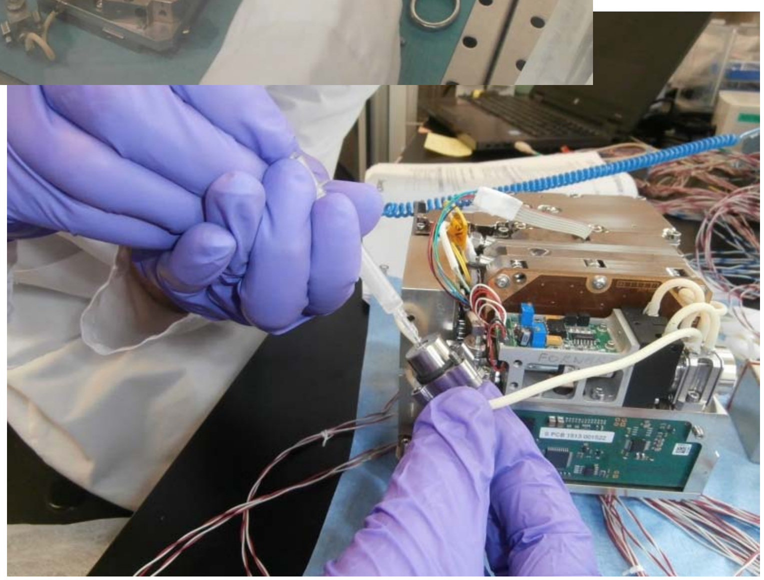
Size	147 x 125 x174 mm
Weight	4.2 kg (full)
Energy	2,2 W (standby) - 3,4 W (incubation)


Complete hardware for one ArtEMISS space bioreactor
2x Sample
reservoirs
Medium
supply
Rad sensors
Reactor programming
& commanding
Data logging &
communication
Power converter from
Biolab line 5V to 12V
gas chamber &
pressure sensor
Liquid culture chamber
gas membrane
mixing (magnetic stirrer)
temperature
sensor
OMU cuvette :
cell density
(absorbance)
photosynthetic activity
(fluorescence)
liquid pumping
Illumination (white LED array)
Hermetically
sealed box
External source of energy and heat required.
QINETIQ

Space bioreactor – intensive training and testing

Breadboards - Science models – Ground models – Flight models
(2009 – 2017)

Challenges for BioProduction in Space



Bio-compatibility/Bio-toxicity

- Biotoxicity of individual materials, and full assembly, with sterilization !
- Biotoxicity prevention, & removal

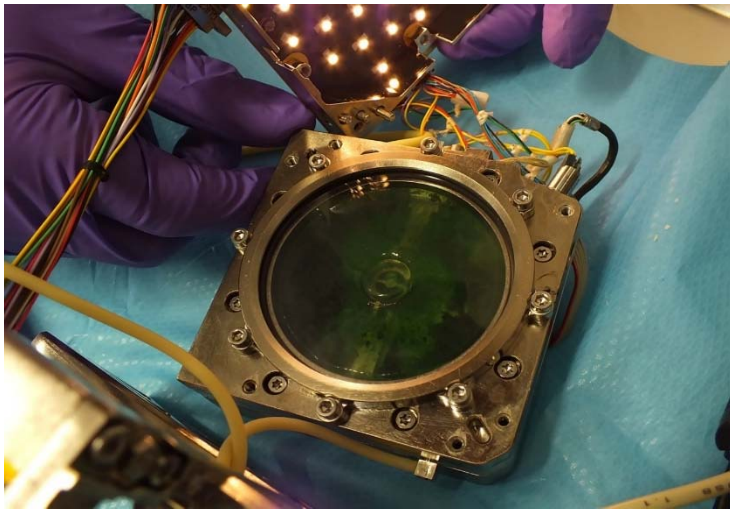
Sterility

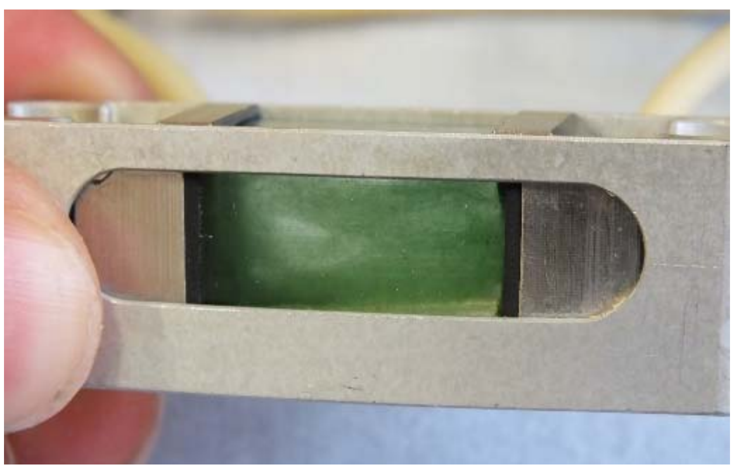
- Complete sterilisation of manufactured space bioreactor materials
- Fully sterile assembly of the liquid loop & reactor components
- Maintain sterility through upload & crew handling

Reversible 'stasis' of cells & proces

- Inactivation & storage of cells
- Successful reactivation of biological cultures & bioprocess in space

Challenges for BioProduction in Space





Gas/liquid separation

- high oxygen production capability cyanobacteria
- engineering appropriate gas control/removal mechanisms
- bubble free liquid loop for measurements

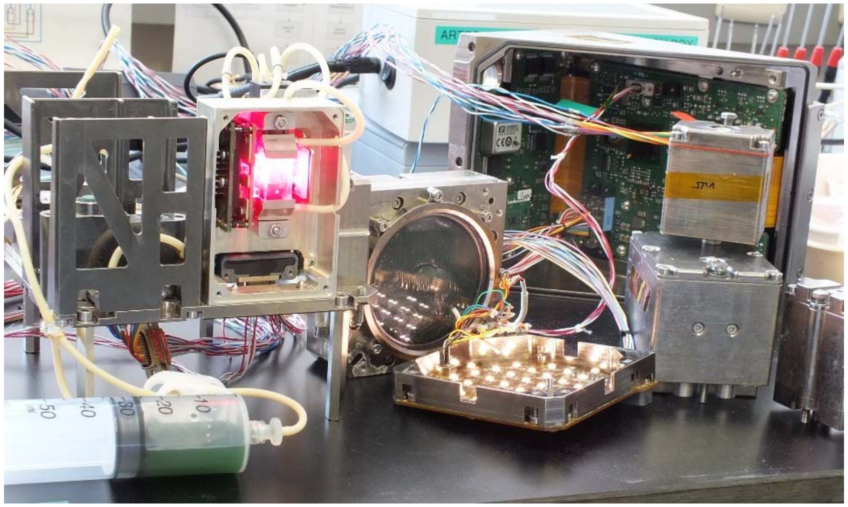
Culture conditions

Optimization of cell culture parameters for

- hermetically sealed bioreactor,
- gas overpressure (oxygen inhibition),
- LED illumination (light spectrum & intensity),
- mixing by magnetic stirring (cell integrity),
- liquid pumping (cell integrity),
- …

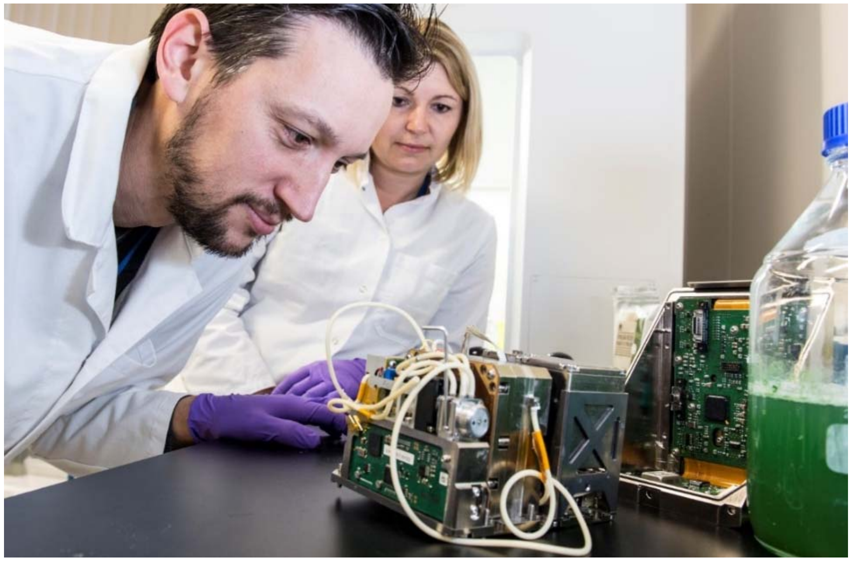
allowing good oxygen release over membrane,
& cell dispersion without flocculation or biofilms,
for optimal growth and production in space

Challenges for BioProduction in Space



Remote reactor control

- Automatic activation & stop
- Automated data collection via temp & pressure sensors, absorbance and fluorescence measurements in liquid loop
- Data logging & data communication
- Bioreactor commanding from ground : light intensity, liquid circulation.



Sampling & Storage & Analysis

- Automated sampling
- Cell fixation and effluent preservation
- Sample storage in ISS and return to earth
- Methods for small sample volumes.

ArtEMISS Space photobioreactor
- in flight measurements & sampling for post flight analysis -

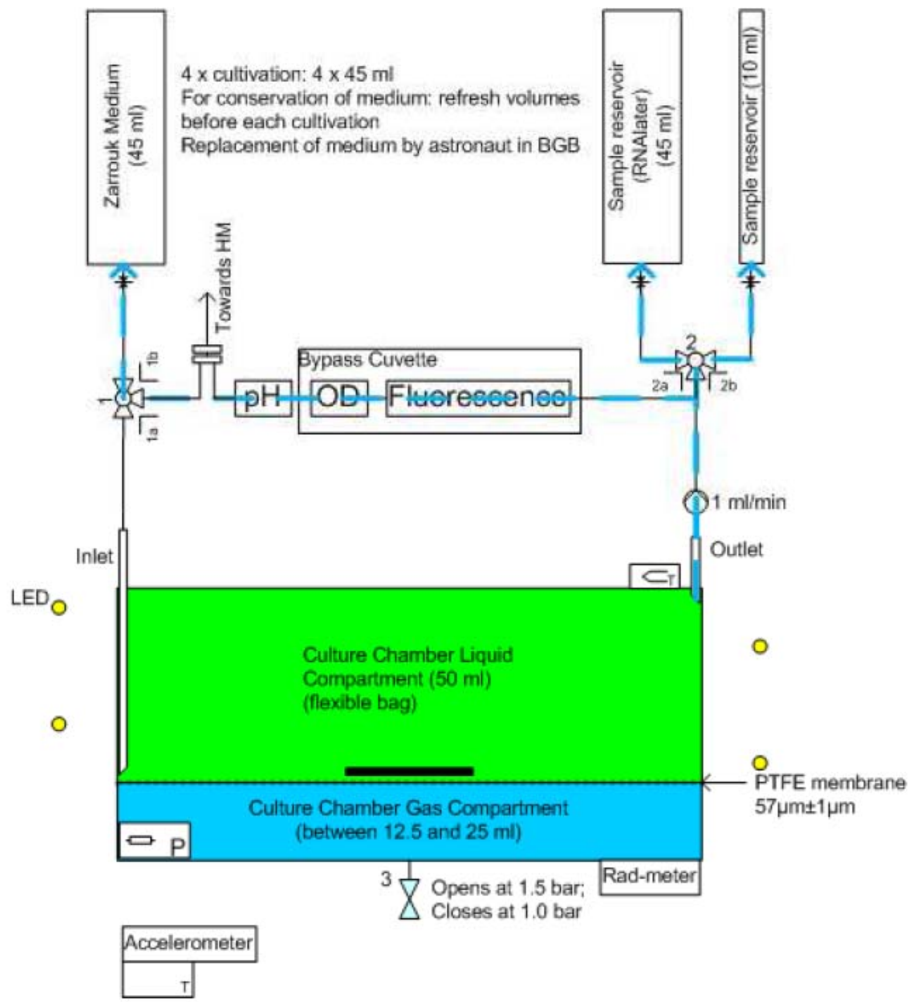
QINETIQ

Measurement of **In flight**

- ~~CO_2 consumption by pH~~
- O_2 production by Pressure
- Cell production by OD
- Cell photosynthetic activity by fluorescence

Sampling for **post flight**

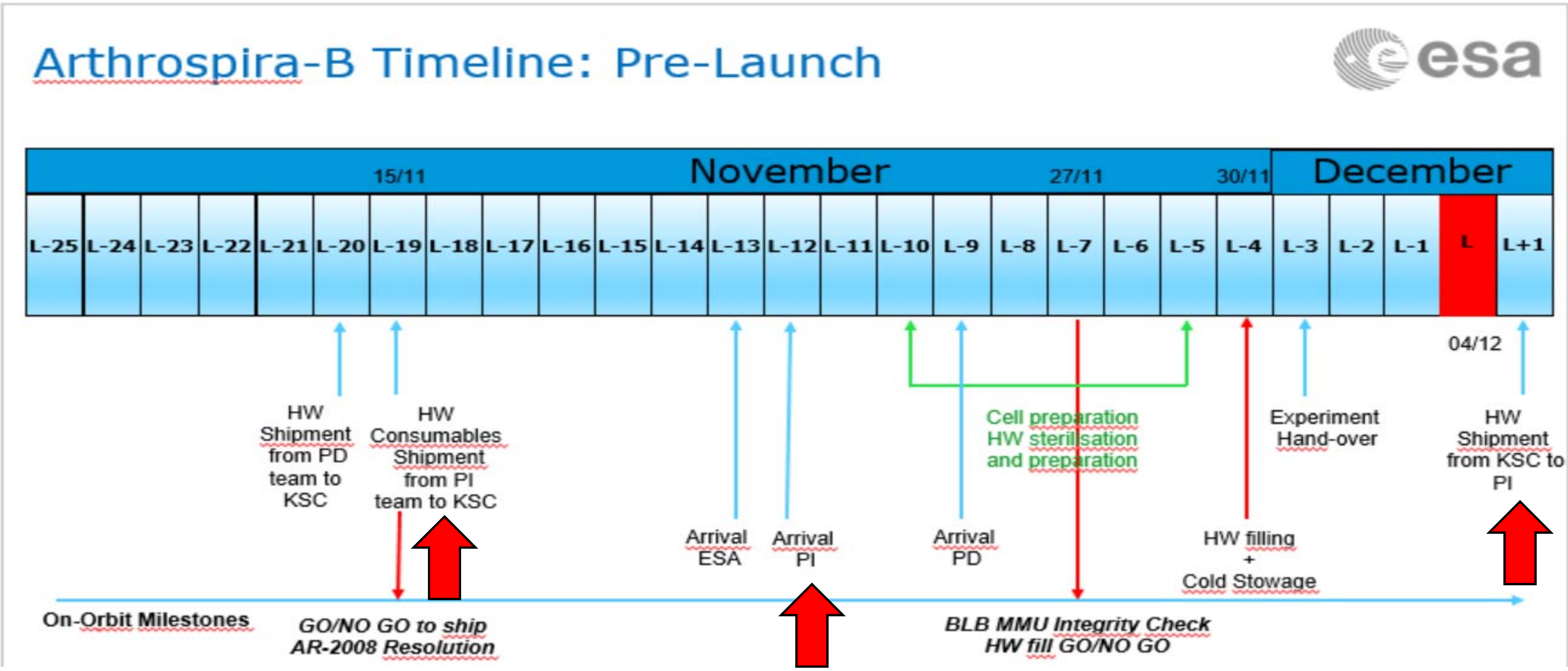
- ~~Microscopy in flight~~
- BioChemical analysis (frozen)
- DNA, RNA, protein, pigment analysis (fixed)
- Post-flight regrowth (live)



LAUNCH
SpaceX CRS-13

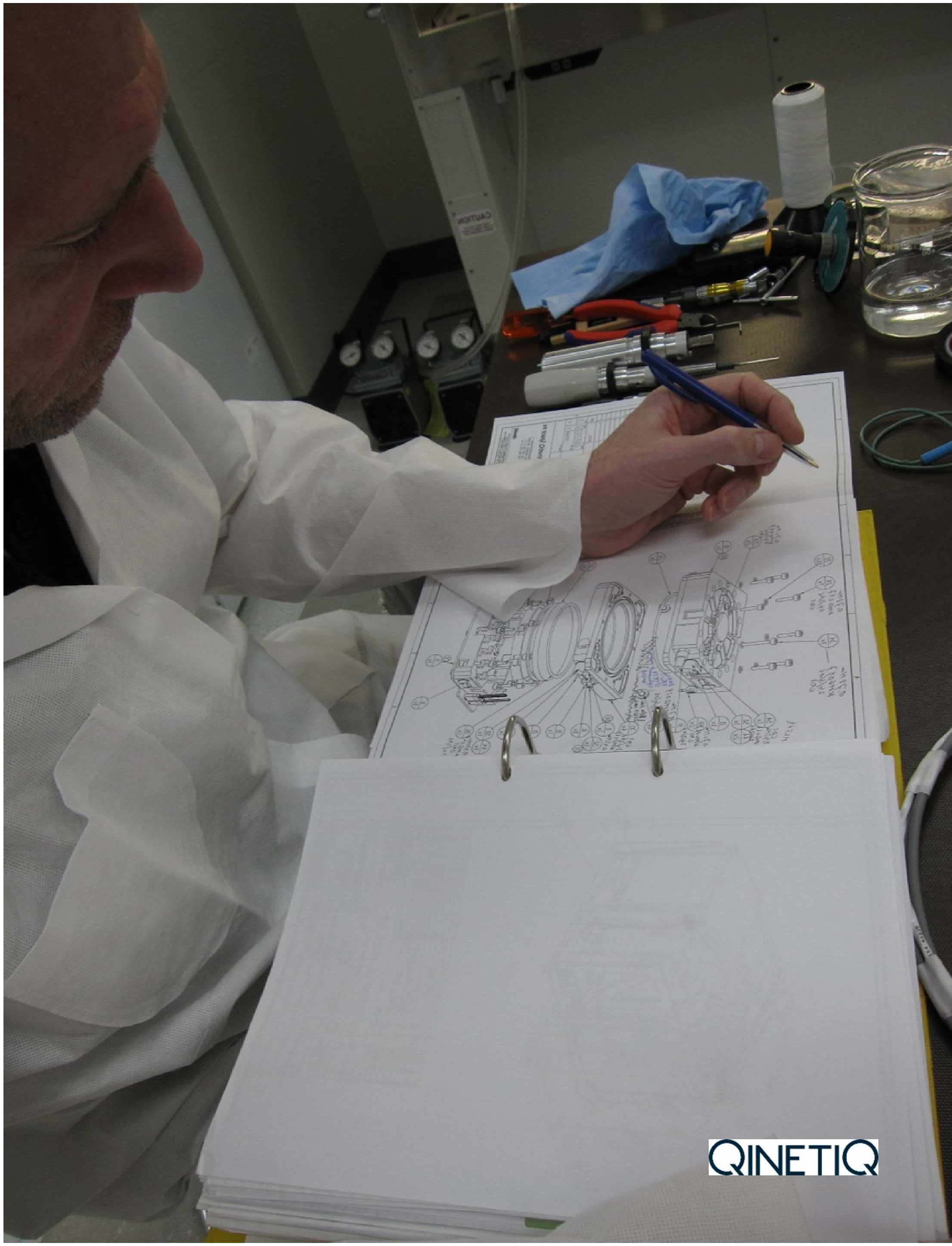
~~**30th of November 2017**~~
4th of December 2017

Time to go space



23 November - 8 December 2017

Chris De Smet of QinetiQ de-assembling the flight models for sterilisation.


QINETIQ


QINETIQ
Hardware engineer working in a sterile manner !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Thursday 7th of December :
Finally : filling the hardware !

1 pers. ‘filling’ (the biologist !)
& 4 pers. checking

LAUNCH

~~30th of November 2017~~
~~4th of December 2017~~
~~8th of December 2017~~
~~9th of December 2017~~

12th of December 2017

"the cold storage team”
a special team (4 pers.) from NASA Houston, to pack all the experiments in special 'aerogel' insulator boxes with cold packs 'bricks' containing 'heavy water‘, which can keep passively the temperature in the box for several days at 4°C (not needing any power), according to the launch and safety regulations, for SpaceX launches.

LAUNCH

~~12th of December 2017~~

~~13th of December 2017~~

15th of December 2017

- Wednesday 20 the of December 2017, at ca. 10h Belgian time, the crew started their activities on our experiment on orbit in space.
- All 4 bioreactors were integrated inside the glove box next to the Biolab, and thereafter placed in the Biolab incubator.
- Thereafter from ground, the contact with our bioreactors in Biolab was restored and at ca. 12:45h the timeline of the 4 reactor was activated.

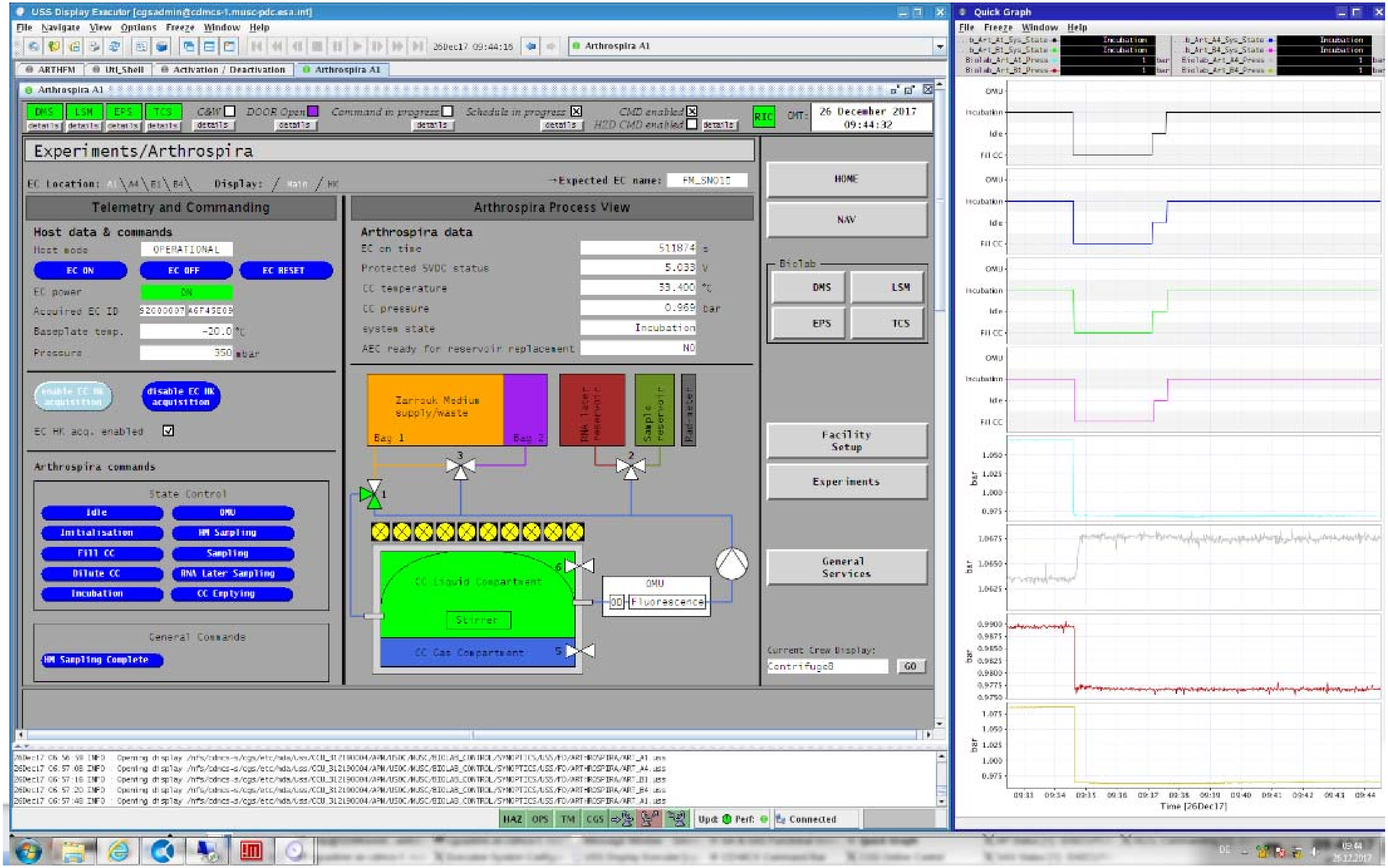
Mark Thomas Vande Hei

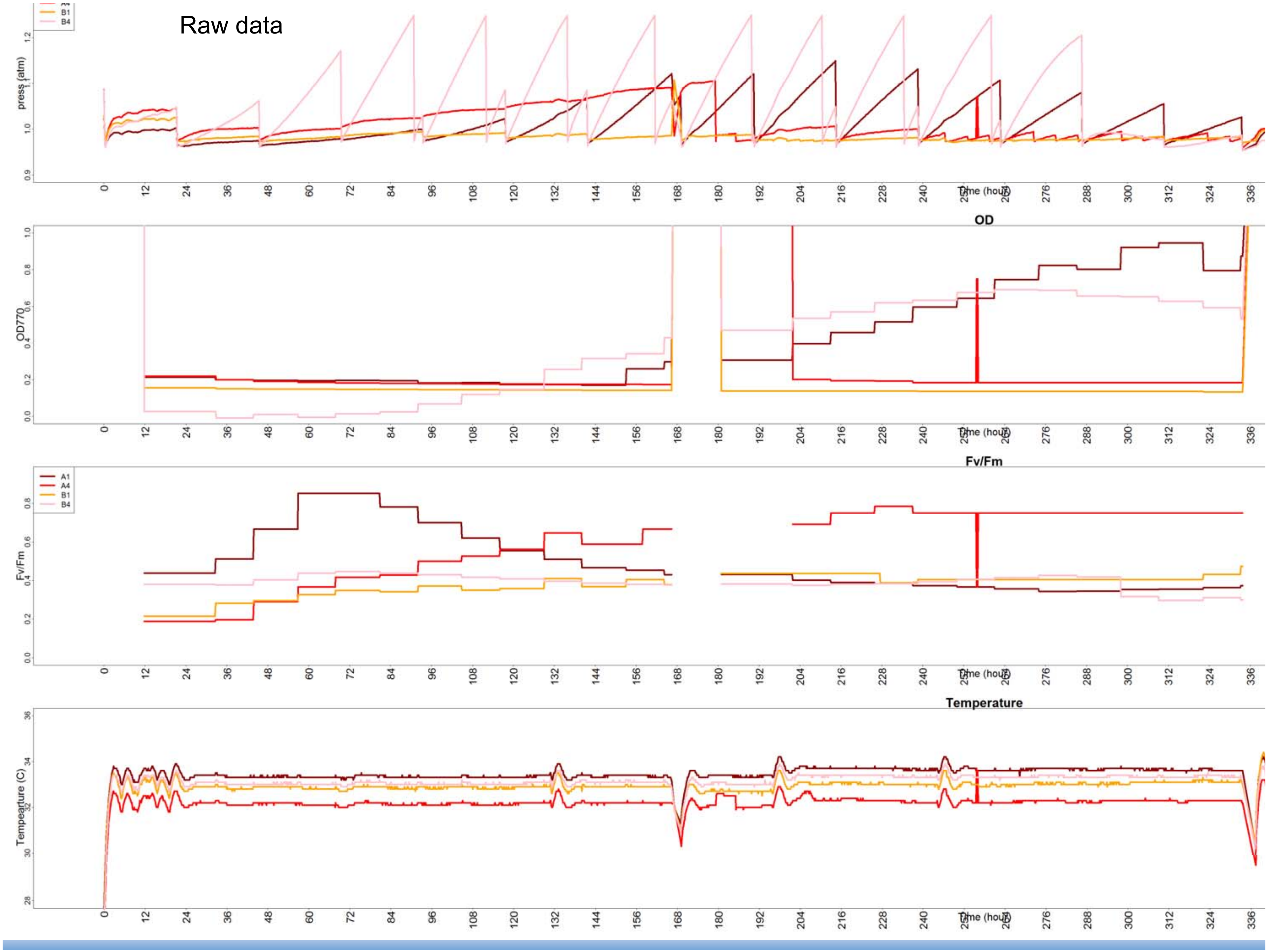
Movie


Inc DU Lock L
P/N BLB-115150
BL1C1CE0E
BLB0EC84E
Rotor B
EC 4
Arthrospira EC
P/N ARTBC-1.1N-1-QS
S/N 4
00240536E
MATERIAL
HAZARDOUS
1
HAZARDOUS
MATERIAL
Arthrospira EC
P/N ARTBC-1.1N-1-QS
S/N 2
MATERIAL

Every Week – start new batch

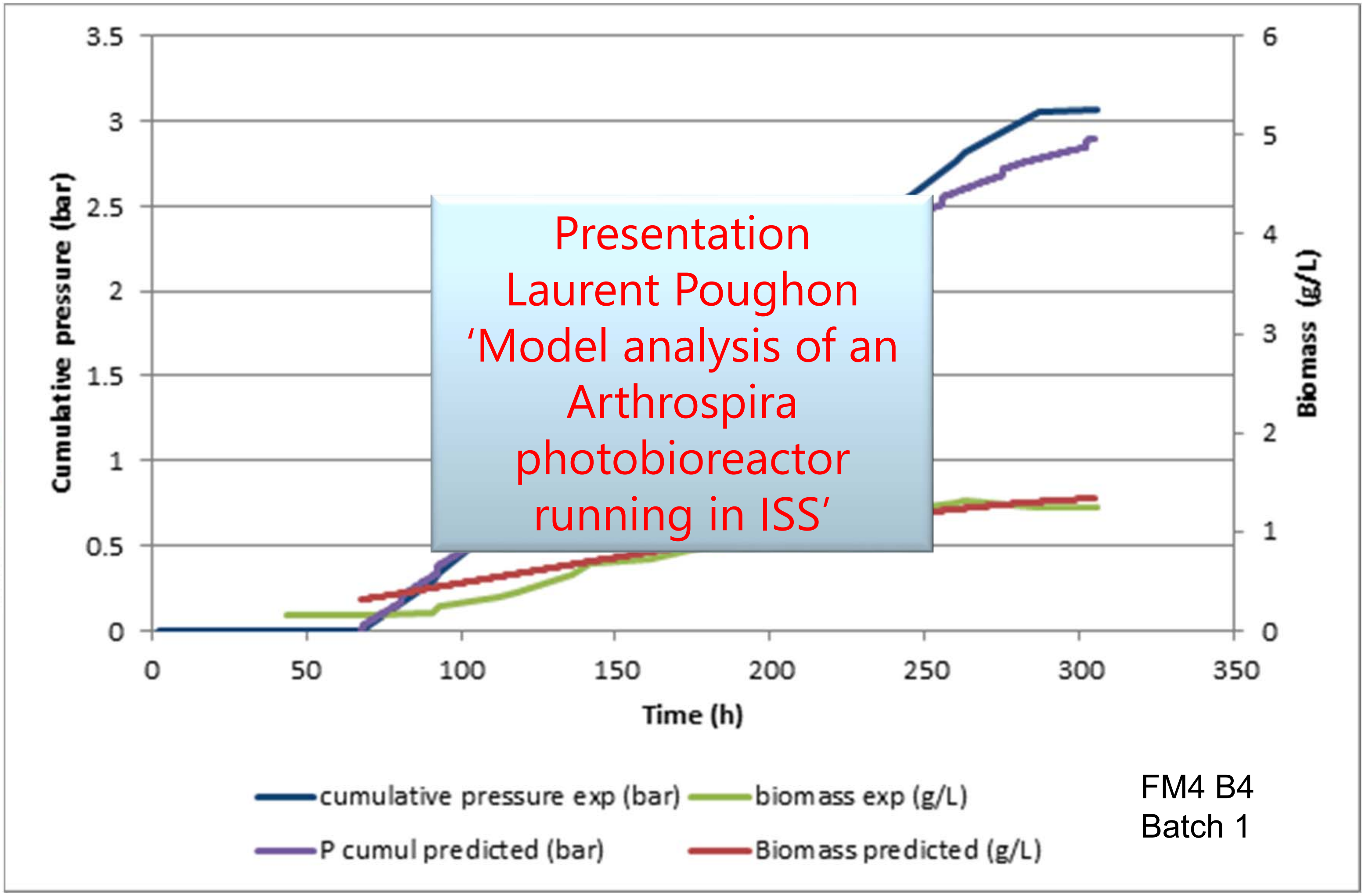
ESA OPS & MUSC & BIOTESC & AIRBUS & DLR, Cologne, DE





Raw data
B1
B4
press (atm)
OD
OD770
Fv/Fm
A1
A4
B1
B4
Fv/Fm
Temperature
Tempearture (C)

It can work as on ground & as predicted



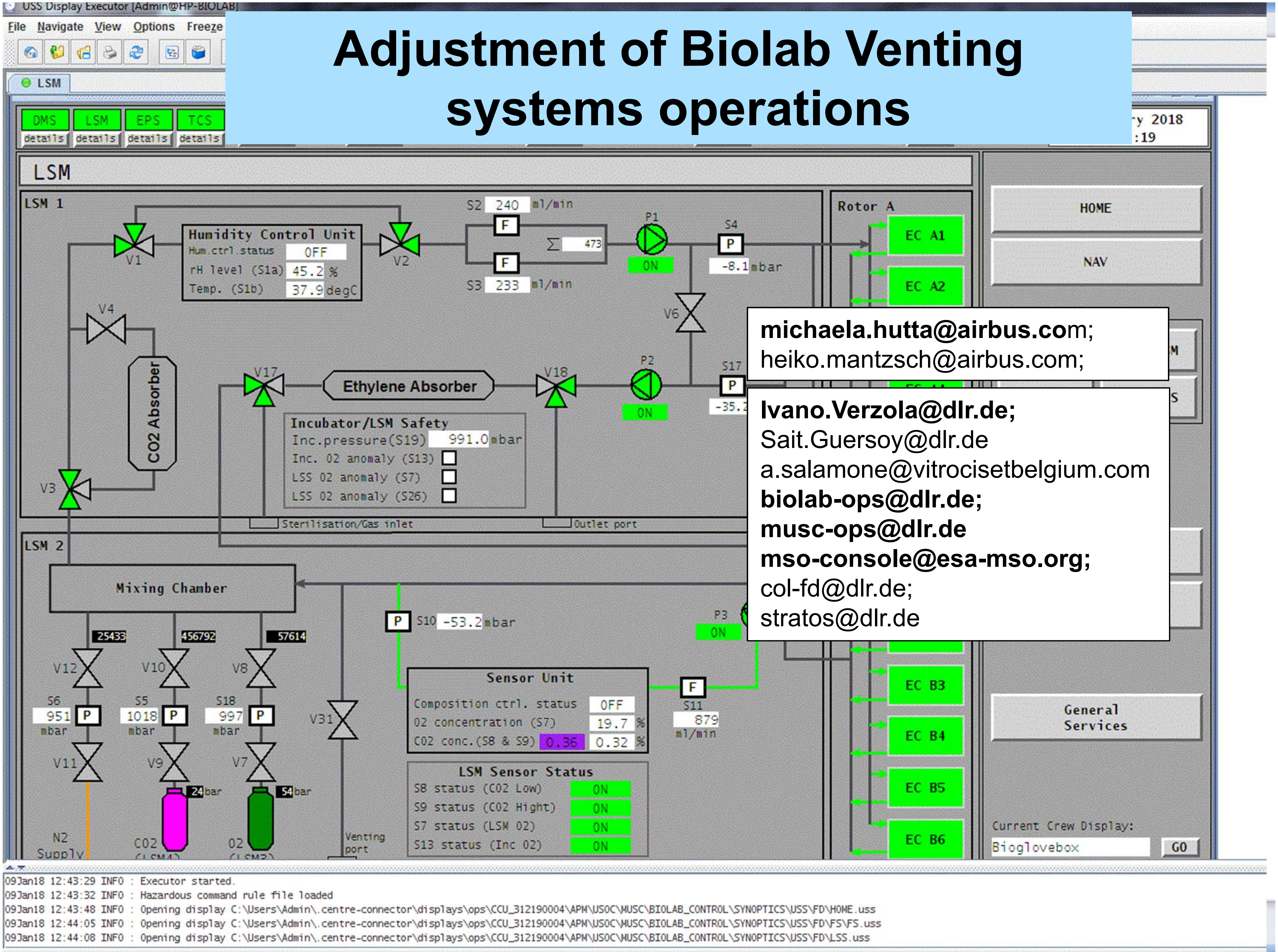
UNIVERSITÉ Clermont Auvergne

Celine
Laurent
Gilles

FM4 B4
Batch 1

BIOLAB COLD SPOT SPONGE
To much humidity in Biolab

Adjustment of Biolab Venting systems operations



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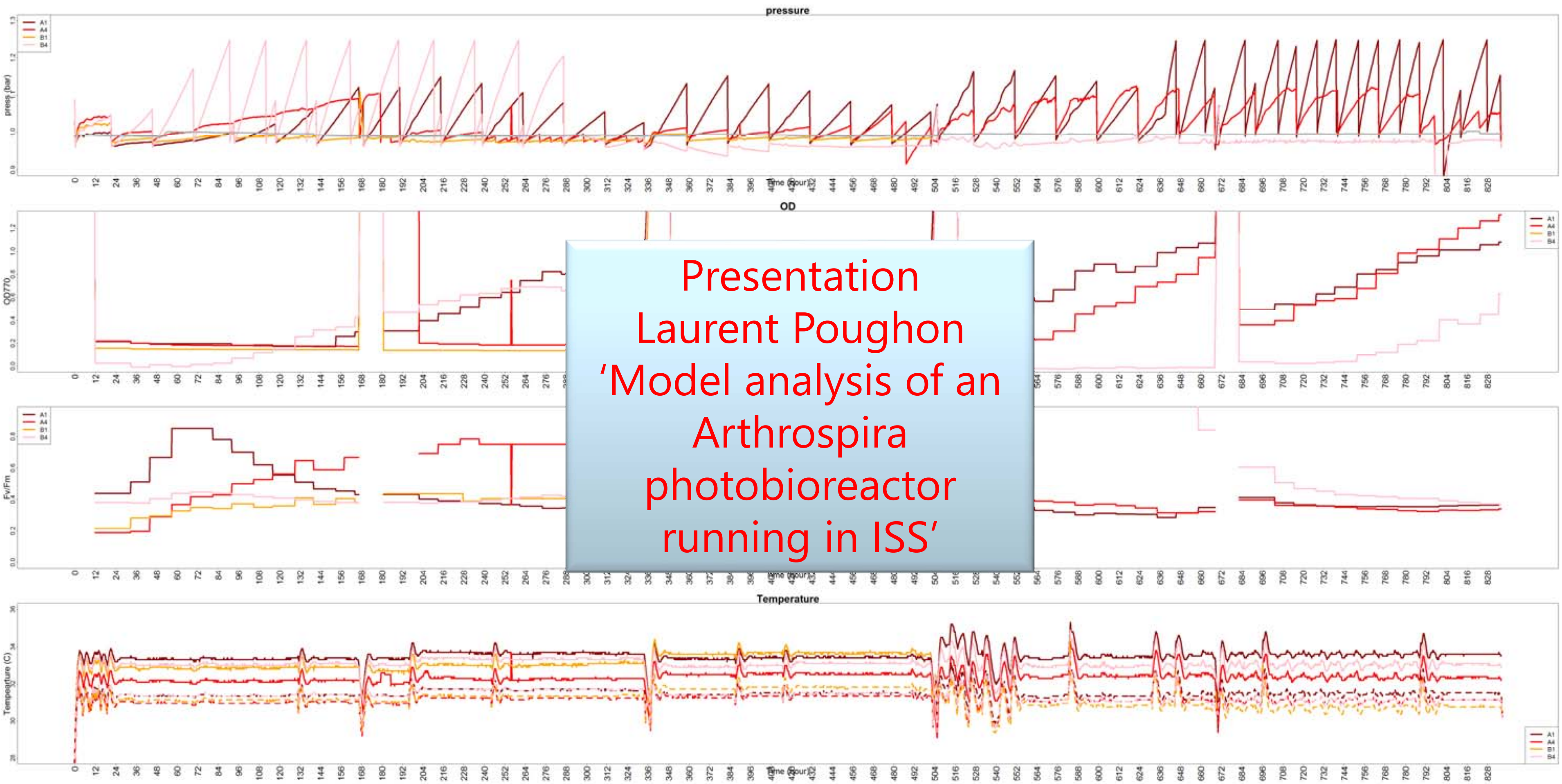
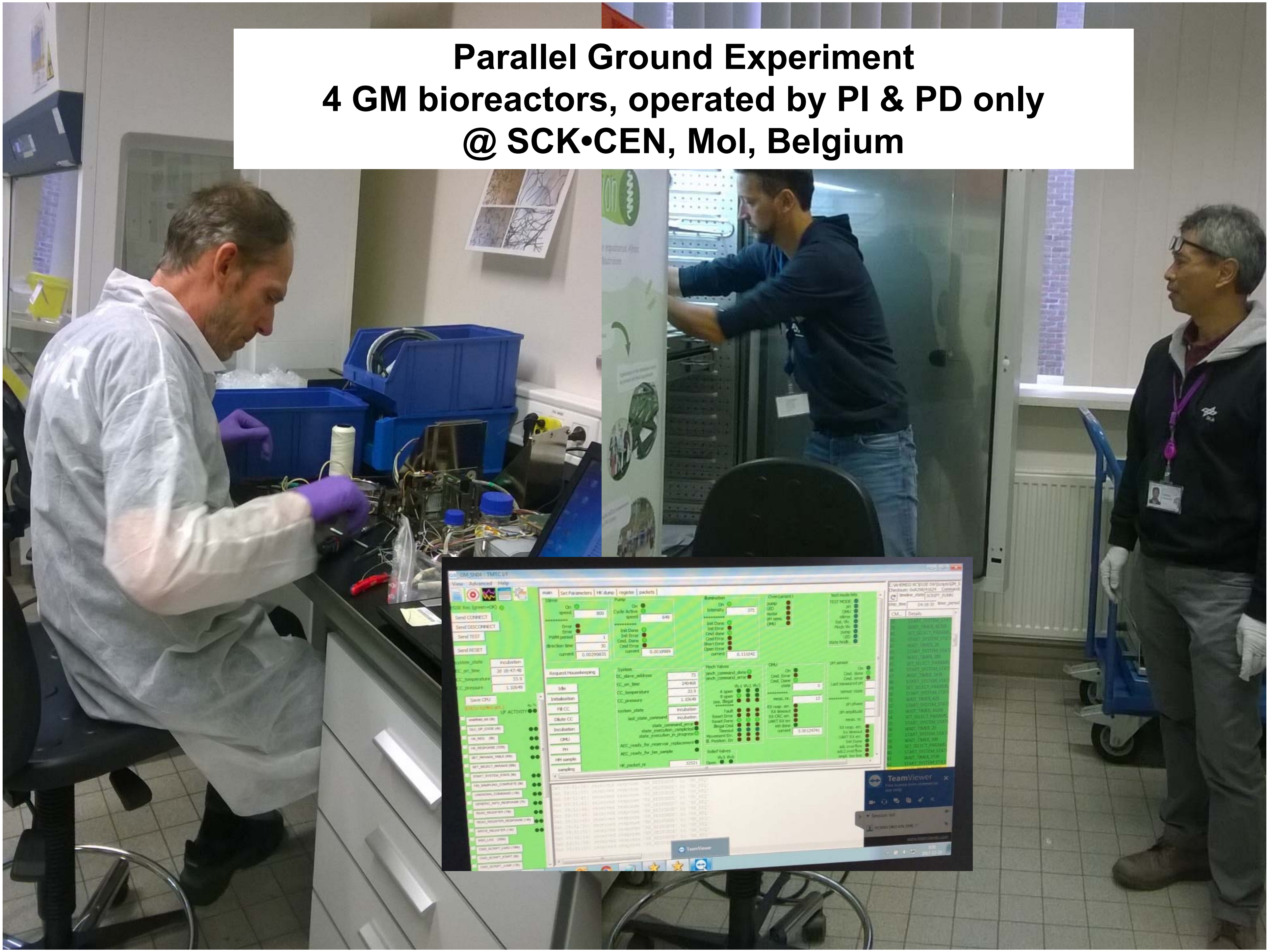
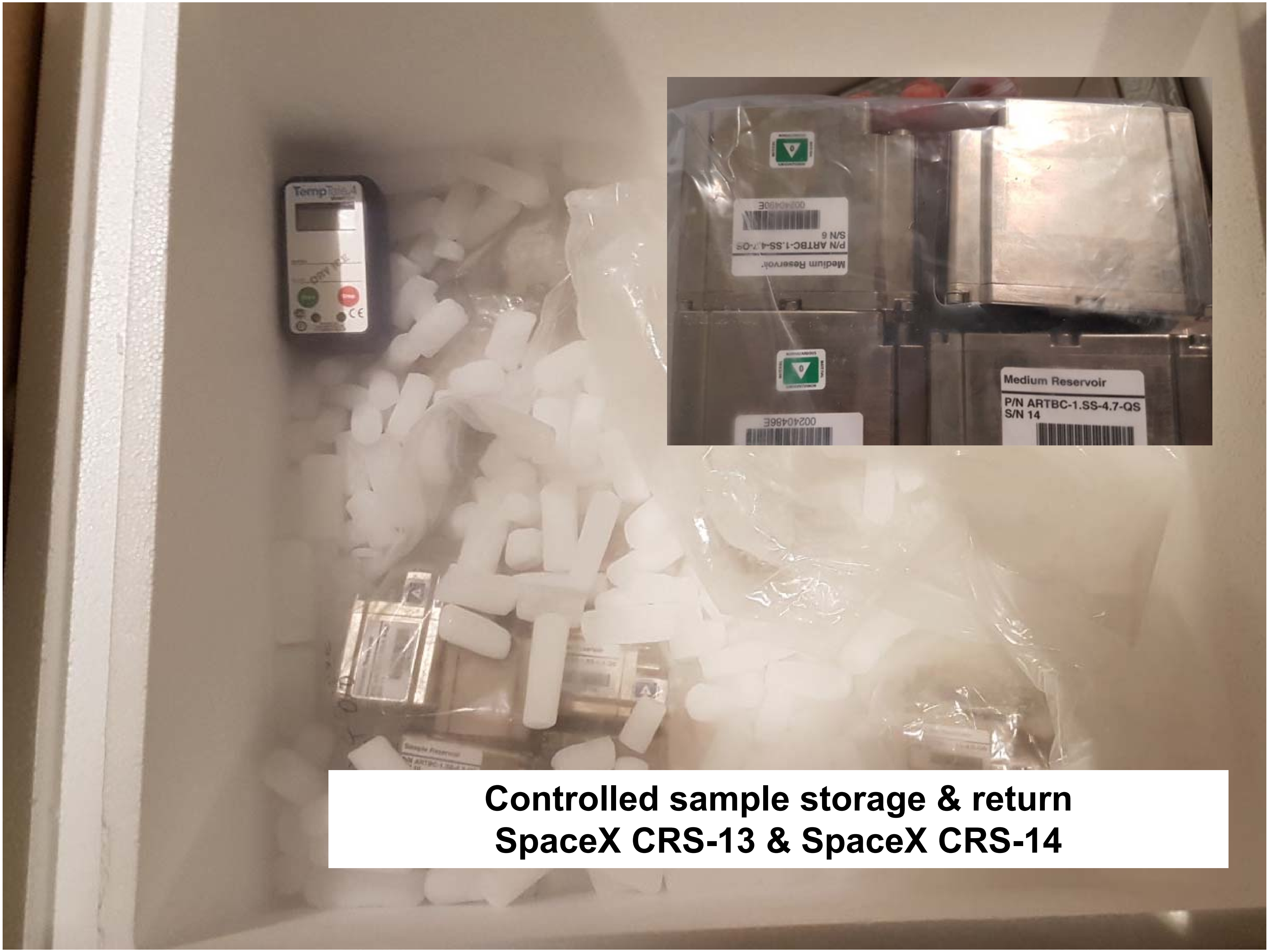
Raw Data → further quantitative and qualitative analysis ongoing



Parallel Ground Experiment
4 GM bioreactors, operated by PI & PD only
@ SCK•CEN, Mol, Belgium





Controlled sample storage & return
SpaceX CRS-13 & SpaceX CRS-14

Full molecular analysis of the space micro-organisms

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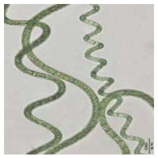
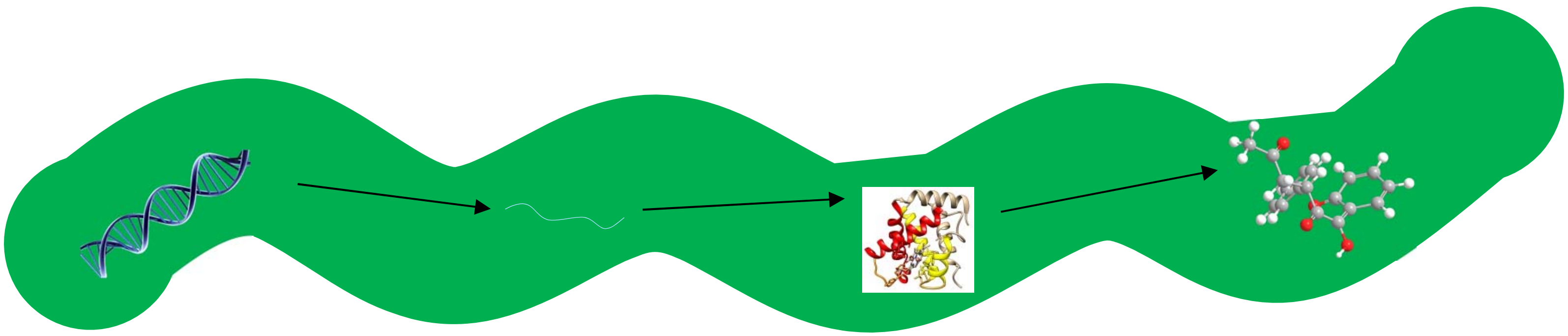
UMONS
Université de Mons



Arthrospira



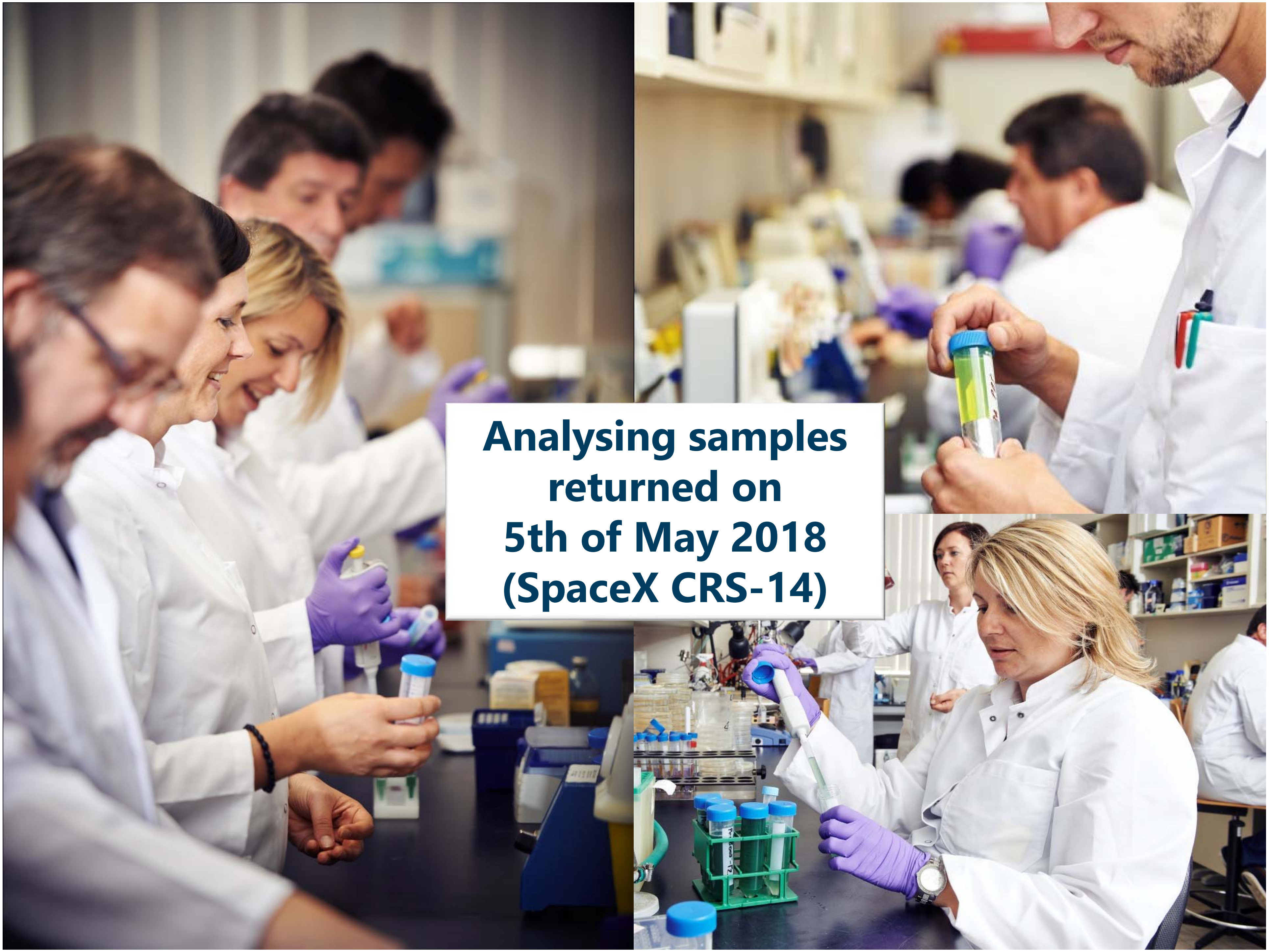
DNA
gene stability
genomics
- seq
- methylation
- …

messenger RNA
gene expression
transcriptomics
- seq
- regulation
- …

protein
protein expression
proteomics
- Protein content
- Expression
- …

metabolite
metabolite production
metabolomics
- lipids
- pigments
- antioxidants
- …

High-throughput Technologies, on small sample volumes, low biomass conc


Analysing samples
returned on
5th of May 2018
(SpaceX CRS-14)

LessonsLearned/Actions

TimeLine

SpaceX CRS-13 Launch
~~30^{th} Nov. 2017~~
~~4^{th} Dec. 2017~~
~~8^{th} Dec. 2017~~
~~9^{th} Dec. 2017~~
~~12^{th} Dec. 2017~~
~~13^{th} Dec. 2017~~
15^{th} Dec. 2017

15 Nov. 2017	Shipping all hardware from Belgium to KSC, Florida US	
23 Nov 2017 - 08 Dec. 2017	4 FM & 4 GM Experiment preparation @ KSC, Florida US	
7- 15 Dec. 2017	4 FM Storage for SpaceX CRS-13 @ KSC, Florida US 4 GM transport to Belgium (dark, 4°C)	
15 Dec. 2017	4 FM Launch SpaceX CRS-13 @ KSC, Florida US (dark, 4°C)	In Space !
17 Dec. 2017	4 FM Arrival ISS & Storage (dark, 4°C)	
20 Dec. 2017 START	4 FM Installation in Biolab ISS by Mark Vande Hei (NASA) & Reactivation of bioreactors after 13 days via remote ground control, via ESA-OPS/MUSC/BIOTESC, Cologne 4 GM manual activation, SCKCEN, Belgium (medium, light 35µE, temp 35°C)	Reactors are ON ! Impact storage & delay !
21 Dec. 2017	After 24h first set of daily data down link, via MUSC/BIOTESC, Cologne	Data connection ON !

Wait ….

TimeLine

Sat 23 Dec. 2017 FM & GM Finally first signs of [partly covered]
Oxygen & biomass production ! (ca. [partly covered] days of delay)

FM4 running as ground, FM2 & FM1 & FM3 slower
GM leakage

Wed 27.12.20[partly covered] [partly covered]sion Batch 1, + 1 week
FM[partly covered] [partly covered]midity problem

Wed 03[partly covered] [partly covered]Mark Vande Hei)
Stop FM3
Remote intervention on FM[partly covered]

Wed 10.01.2018 Stop Batch 2, Start batch 3 (Mark Vande Hei)

13.01.2017 *FM3 & Live Sample return [partly covered]*

Wed 17.01.2018 Stop Batch 3, Start batch 4 [partly covered]

STOP Wed 24.01.2018 Stop Batch 4 (Joseph Acab[partly covered]

Storage in ISS

Wed 05.05.2018 Frozen Sample & rad sensor return with SpaceX CRS-14
09.05.2018 in SCKCEN, 14.09.2018 inspection

Bio-process ON !

Cell viability confirmed.

[partly covered]emote reactor control !

Cultu[partly covered] [partly covered]nicity confirmed until week 3 !

Space biomass & effluent collected !

Impact launch & start : temp, vibrations, underpressure, … ?

Humidity problem… ?
Impact Biolab - Bioreactors

Not do these kind of experiments over Christmas !

Data communication/interface & Bioreactor commanding

Additional 'feedback' : vision (bubbles, stirring, color), pH-disCO2, liquid pressure, dis02, humidity, …

Fine tuning of the modelling for predictive control

…

& Christmas, end of th[partly covered] [partly covered]pany clos[partly covered] [partly covered]mily events, travel, …

Waiting for bioreactors to return to SCK•CEN / QinetiQ

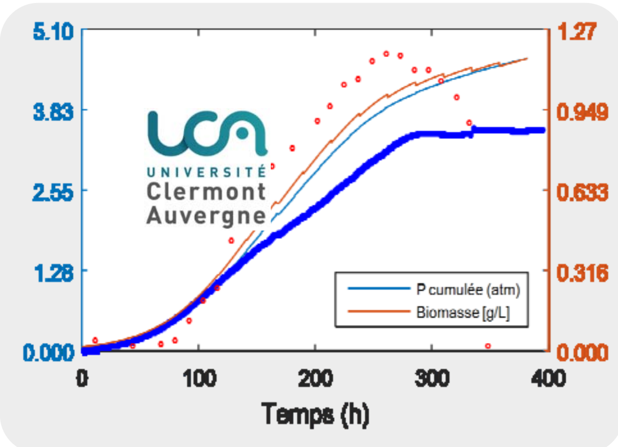
Successful bioreactor in space

Mark Vande Hei working on the bioreactor in Biolab glove box in ISS (Source : ESA)

First time mini photo-bioreactor with gas-liquid separation built, certified, uploaded and running in space, with live data feedback from space and ground commanding

- 4 bioreactors launched to ISS with SpaceX CRS-13 (15.12.2017)
- 13 days of inactivation (cooled) during upload & storage (7–20.12.2017)
- Installation in the Biolab incubator in the Columbus module of ISS by crew (Mark Vande Hei, NASA & Joseph Acaba, NASA) (20.12.2017)
- Automated bioreactor reactivation by commanding from ground
- Total bioreactor operation duration in space of 35 days (20.12.2017 – 24.01.2018)
- 4x sampling of reactor effluent and biomass during the 5 weeks run
- 4x new feed supply to the reactor & sample storage in ISS by crew
- Good Gas – Liquid separation, at least for some phases
- Live bioreactor monitoring from ground & daily data download link
- Ground commands to collect samples and adjust settings (temp, light intensity, fluid circulation)
- Sample return with SpaceX CRS-13 (13.01.2017) & SpaceX CRS-14 (5.5.2018)

Successful bioprocess in space - Yes it also works in space !



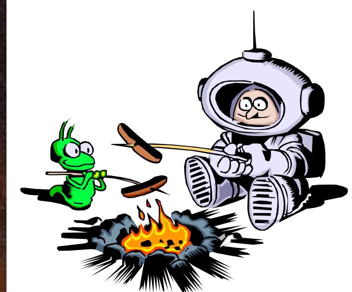
Oxygen and biomass production in bioreactor FM4-B4 in space, compared to predictive model

First long-term culture of an axenic photosynthetic bacterium in ISS

First microbial production of oxygen and edible biomass in space

- Culture & Bioprocess successfully reactivated in space after 13 days of stasis
- Active photosynthetic culture of *Arthrospira* for more than 1 month in ISS
- Culture axenicity maintained in space for at least 3 weeks (final timepoints to be analysed)
- 'Good' oxygen and biomass productivity in the bioreactor in space, compared to model
  – *quantitated analysis ongoing*
- Oxygen produced was provided to the cabin, for consumption by the crew
- *Post-flight biochemical and biomolecular analysis (genomic, transcriptomic, proteomic) analysis of reactor effluent and biomass harvested from the bioreactors is ongoing*

‘spirulina’ as part of the low-weight, low-waste, high-nutrient diet of astronauts during space flights



Arthrospira as food supplement for space

Development of recipes & healthy menu

Microbiome & health studies on mice, with irradiation

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Universiteit Antwerpen

Acceptance test during Bedrest studies

Microbiome studies on human volunteers in isolation

Belgian PE Antactica station, Dec. 2017

Mars Desert Research Station (MDRS), Crew 190 (UCL to Mars), March 2018

Bibliography @ http://www.melissafoundation.org/

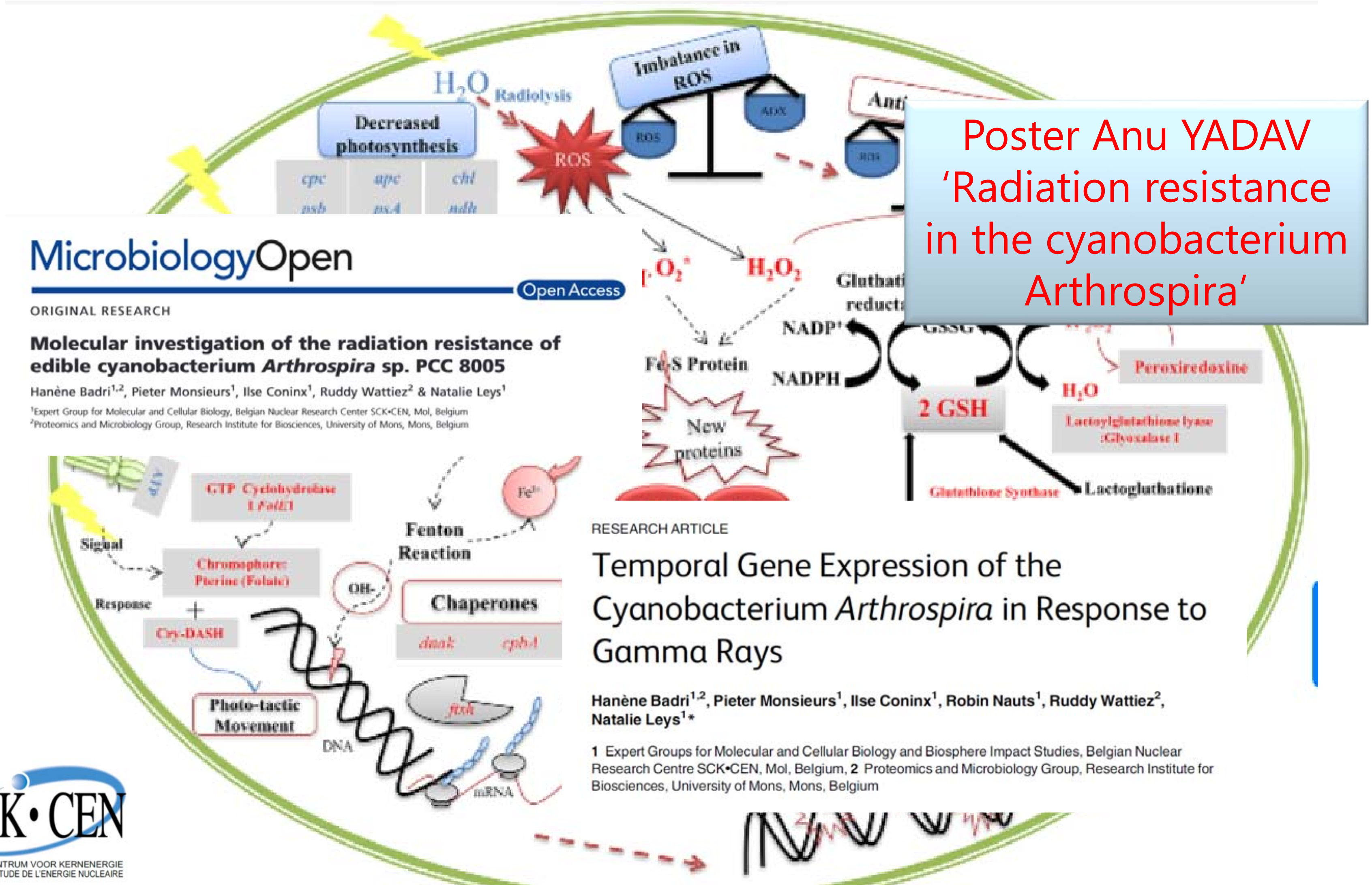
MELiSSA- Step-wise Space flight strategy

- FEMME concept paper study on small bioreactor for O2 production by Arthro + O2 consumption by BACTERIA (design) – ESA, NL
- MASK bioreactor with Arthro & control by light (mathematical model, molecular) (ground exp.) – UBP, France
- ARTEMISS bioreactor with Arthro O_2 production (mathematical model, molecular) (ISS flight exp.) - SCK•CEN, B (+QinetiQ, UCA, UMons)
  - » Arthrospira-B : fed-batch reactor (flight Dec. 2017 – Jan. 2018)
  - » Arthrospira-C : continuous reactor (flight TBD)
- BIORAT-1 Coupling Photobioreactor compartment with a RAT/Mouse consumer compartment bioreactor, controlled by light – RUAG, CH
- URINIS Urine treatment compartment – Ugent, B (+ SCK•CEN, UMons)
- BIORAT-2 Biorat-1 + Oxygen control with two Nitrogen sources – Umons, B
- BIOMAN bioreactor for O2 production by Arthro + O2 consumption by MAN


From Space to Earth ….
Our Space Research
Biopharma applications
Health promoting
Radiation protection
Agriculture & food
Healthy diet
Waste Treatment
Resource management
Water treatment
Environmental health
….

Molecular mechanisms of ionising radiation resistance

- how to protect against & repair from radiation damage -



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Spirulina as food supplement in DR Congo

- SCK•CEN contribution to the organisation of 'Enterpreneurs for Enterpreneurs'
- project to help fight the malnutrition of Congolese c development of local spirulina culture.
- 'Pilot' culture & harvest & cooking at SCKCEN run b
- construction of an Arthrospira sp. pilot farm in the re

Presentation
Felice Mastroleo
'Mission to Mars
Inspires food project
in Congo'


First test bassin in Mooto


Meeting with local universities for scientific follow-up

Dr. Felice Mastroleo

Thanks to…

sponsors at Belspo/ESA

Belgian Science Policy Office

belspo

esa

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Wietse Heylen, Ilse Coninx, Pieter Monsieurs, Felice Mastroleo,

different groups of SCK•CEN

'Molecular and Cellular Biology Group' (MCB)

ArtEMISS project partners

MELiSSA

Céline Laroche, Laurent Poughon, Gilles Dussap, Christel Paillé, Christophe Lasseur, Ruddy Wattiez,

…

Only possible with the help of many

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....

THANK YOU ALL
for supporting the preparation and operation of this bioreactor in space


Thanks to
my personal
space crew
MELISSA
SPACEX

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FOR NUCLEAR SCIENCE AND TECHNOLOGY

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Space Summer School
June 25 - July 6, 2018
SCK•CEN, Mol, BELGIUM

For University Students

- Interuniversity Academic
  Courses & Training, e.g. BNEN
- Bachelor thesis projects
- Master thesis projects
- PhD thesis projects
- Summer Schools

academy.sckcen.be
Upcomming events
Deadline June 4th,
abstract 18th may

For School Students and Teachers

- Information days for teachers at SCK•CEN
- Monthly school visits
- Internship at SCK•CEN (e.g. for thesis)
- Thematic days at or supported by SCK•CEN
  Bv. ‘space days’, ‘greenlight for girls & boys’, ‘Printemps des Science’…

SCK•CEN

Institute for Environment, Health and Safety

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www.sckcen.be

https://www.sckcen.be/en/Technology_future/Space

http://www.melissafoundation.org/

http://www.esa.int/Our_Activities/Space_Engineering_Technology/Melissa

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