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Looking for signs of life on Mars

The Packaging Integration and Interfacing of Micro System Hardware for the ExoMars Life Marker Chip Instrument

7th ESA Round-Table on MNT for Space Applications
September 13-17, 2010
ESTEC Conference Center, Noordwijk, The Netherlands

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- LMC integrated optics
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ExoMars elements and planning

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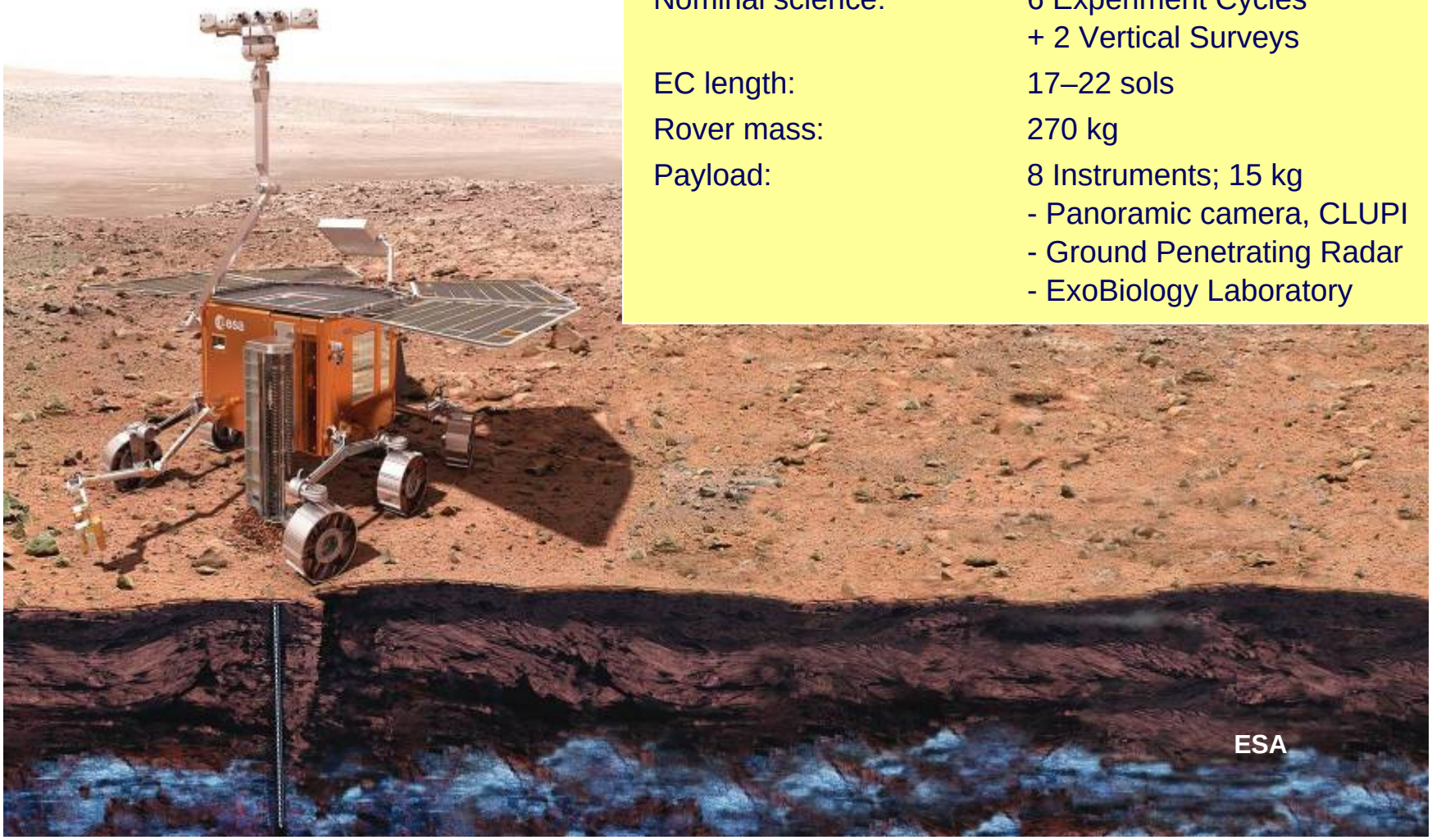
The ExoMars Rover

Nominal mission:	180 sols (185 Earth days)
Nominal science:	6 Experiment Cycles + 2 Vertical Surveys
EC length:	17–22 sols
Rover mass:	270 kg
Payload:	8 Instruments; 15 kg - Panoramic camera, CLUPI - Ground Penetrating Radar - ExoBiology Laboratory



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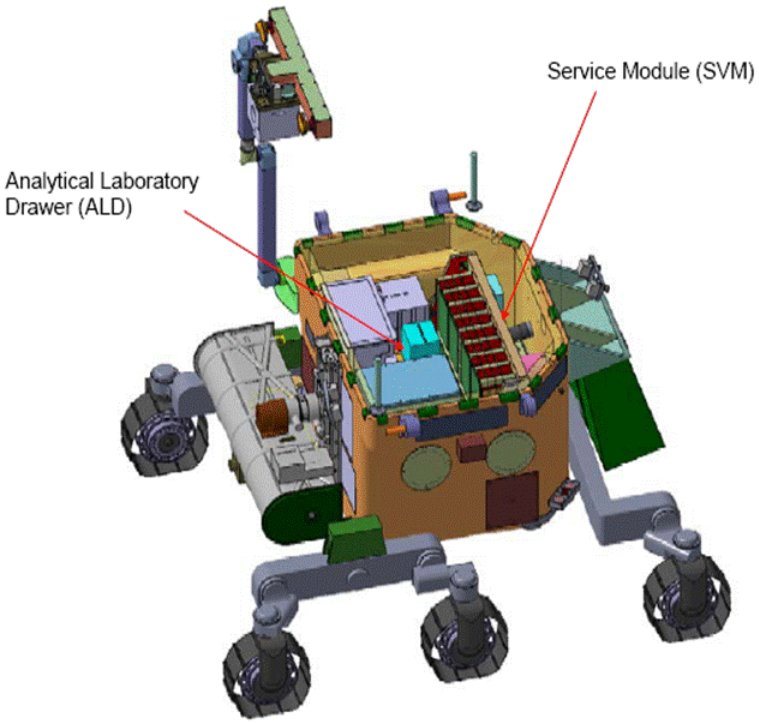
Rover Payload and Life marker Chip

- Life Marker Chip is a instrument designed for the ExoMars Pasteur payload (launch: 2018)
- Designed to explore signs of extinct and extant life
- The University of Leicester is the Prime contractor
  partners: Kayser Italia, DLR, Magna Parva, SSTL, Open University,Cranfield University
- Dutch Space and LioniX team to contribute the key Analysis S/S *(based on national funding from the NSO)*



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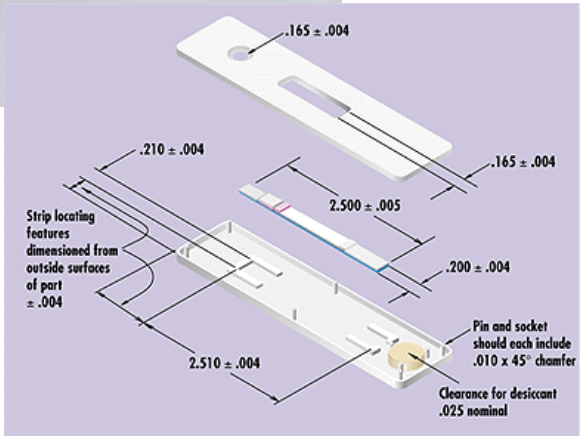
Inspiration for LMC



Pregnancy test kits allow detection of new life…

Can we use this technology also for detection of life on Mars ?

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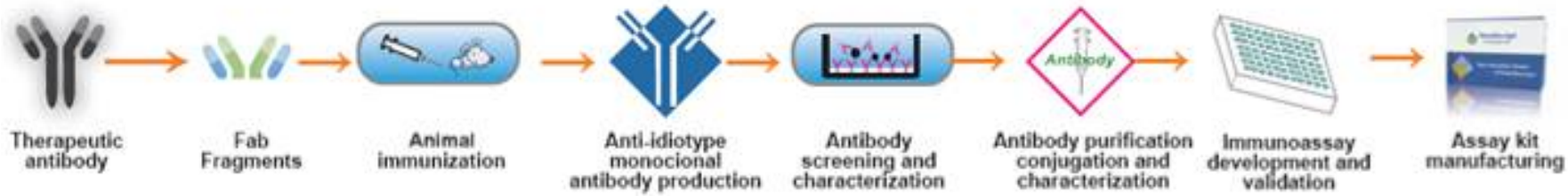
Immunoassays

- **A home pregnancy test** is a tool that allows women to determine if they are pregnant. These tests measure Human chorionic gonadotrophin (hCG), a hormone that is secreted in urine during pregnancy. Human chorionic gonadotrophin is measured using a technique known as an *immunoassay*, which involves a complex reaction between the hormone and various protein antibodies.
- An **immunoassay** is a biochemical test that measures the concentration of a substance in a *biological liquid*, typically serum or urine, using the reaction of an antibody or *antibodies* to its antigen



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Immunoassay detection on Mars

Unlike the pregnancy test we do not know what biomarkers we are looking for, therefore the instrument is to target a broad spectrum of biomarkers

LMC target - biomarkers and control markers

- *Extinct Life – preservation / diagenetic products of ancient life (geo-molecules)*
- *Extant Life – short lived products of present life (bio-molecules)*
- *Abiotic organics – examples of meteoritic in-fall, preservation / diagenetic products of early Mars organics inventory*
- *Spacecraft contamination markers – mainly micro-organism markers*
- *Assay control markers – for example synthetic organic molecules*

- See next slide for full list generated during LMC Mars Biomarker Workshop (Leicester, UK - May 2006) see Astrobiology 7, 4, 578-604
- It is the intention to develop a set of assays to detect 20 different biomarkers from this list

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LMC target list

Extant		Extant		Meteoritic	
1	ATP	26	Melanoidins	47	Napthalene
2	Phosphoenolpyruvate	27	Sediment/cell extracts: 1. Acid mine drainage	48	Coronene
3	Acetyl phosphate	28	Sediment/cell extracts: 2. Methanogens	49	Pyrene
4	cyclic AMP	29	Sediment/cell extracts: 3. Cyanobacteria	50	1,3 Dimethylbenzene
5	Generic pyrimidine base	30	Sediment/cell extracts: 4. Mars Energy Users	51	1,4 Dimethylbenzene
6	Generic purine base	31	Sediment/cell extracts: 5. Extract/abiotic mix	45	Generic amino acid
7	DNA			52	isovaline
8	Nicotinamide (generic NAD, NADP)	Extinct		53	a-aminoisobutyric acid
9	Flavin (isoalloxazine ring)	32	Generic isoprenoid	54	Generic aromatic carboxylic acid
10	Fe-S centres	33	Pristane	55	Experimental abiotic
11	Quinones	18	Phytane		
12	Generic carotenoid	34	B-carotane	Contaminants	
13	Phycocyanin	35	Tetramethyl benzenes	56	Generic fungal
14	Thiol Esters	36	Tetramethyl cyclohexanes	20	Teichoic Acid
15	Generic porphyrin	37	Squalane	21	LPS
16	Chaperons	38	Generic ABC terpane	57	Staphylococcus
17	ATP Synthase	39	Generic hopane	58	Streptococcus
18	Phytane	40	Gammacerane	59	Bacillus
19	Fatty acids (1 or 2)	41	Generic diasterane	60	Micrococcus
20	Teichoic Acid	42	Generic sterane	61	Pseudomonas
21	LPS	43	Generic porphyrin (ancient)	62	Dipicolinic acid
22	Ectoine	44	Generic Straight-chain	63	Hydrazine (or equivalent fuel marker)
23	Trehalose	19a,b	2 individual Fatty Acids		
24	Squalene	45	Generic amino acid		
25	Diploptene	46	Quaternary carbon alkane		

Table result of LMC Mars Biomarker Workshop (Leicester, UK - May 2006) see *Astrobiology 7, 4, 578-604*

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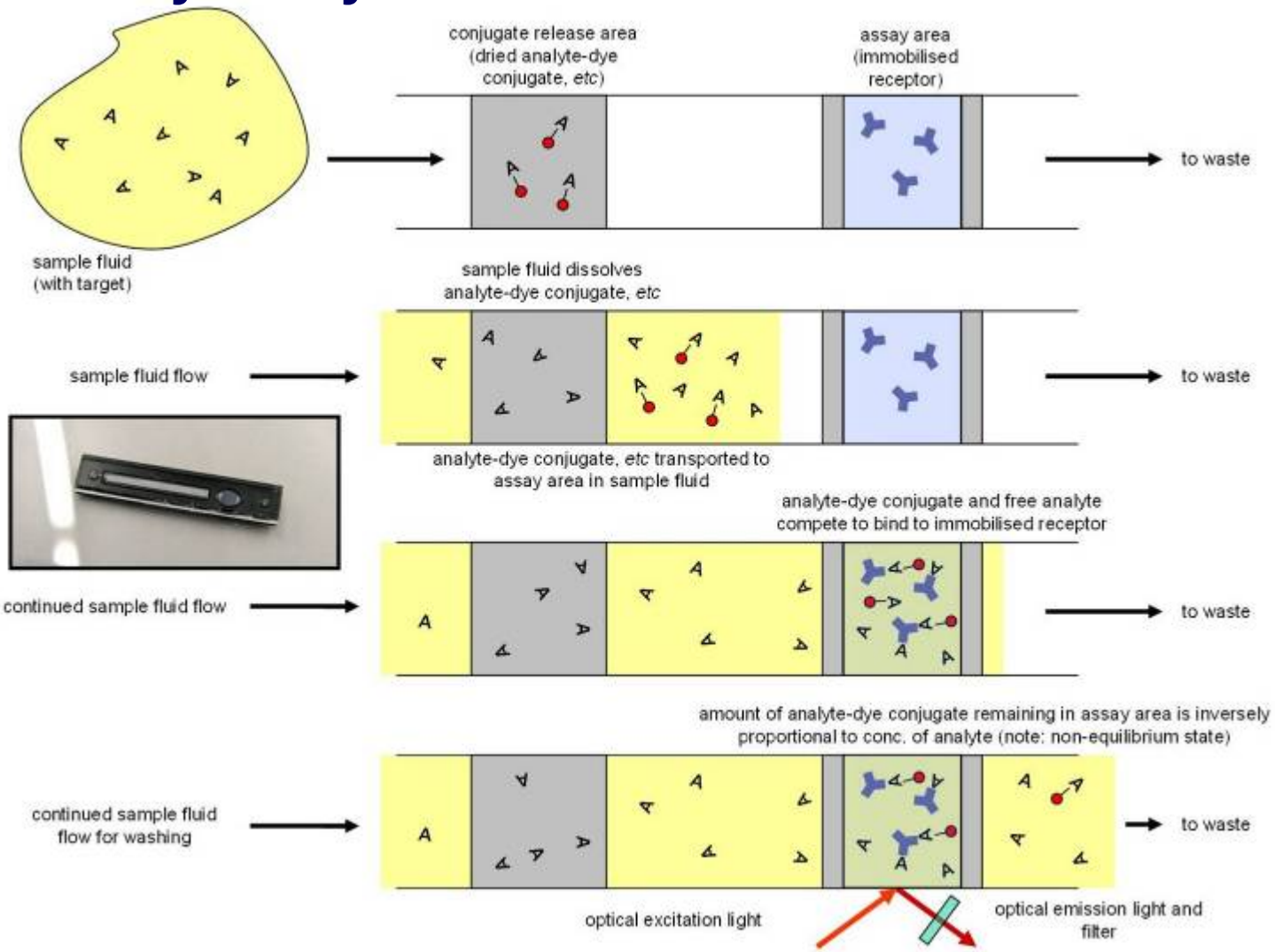
Immunoassay Analysis



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Sample preparation

To run an **immunoassay** a *biological liquid* is required.

The Martian soil sample is therefore to be processed to a concentrated liquid containing biomarkers

(this sample extraction chemistry is the responsibility of Imperial College)

1. The biomarkers are extracted by adding liquids to the sample and a combination of heating and sonication
2. Evaporation of the liquids is prevented by pressurisation of the system (at the ~ 8 mbar Mars pressure liquids will boil off)
3. The sample liquid is purified, desalted, and filtered

After preparation the liquid sample containing the biomarkers is pumped in a very small lab on a chip system for analysis

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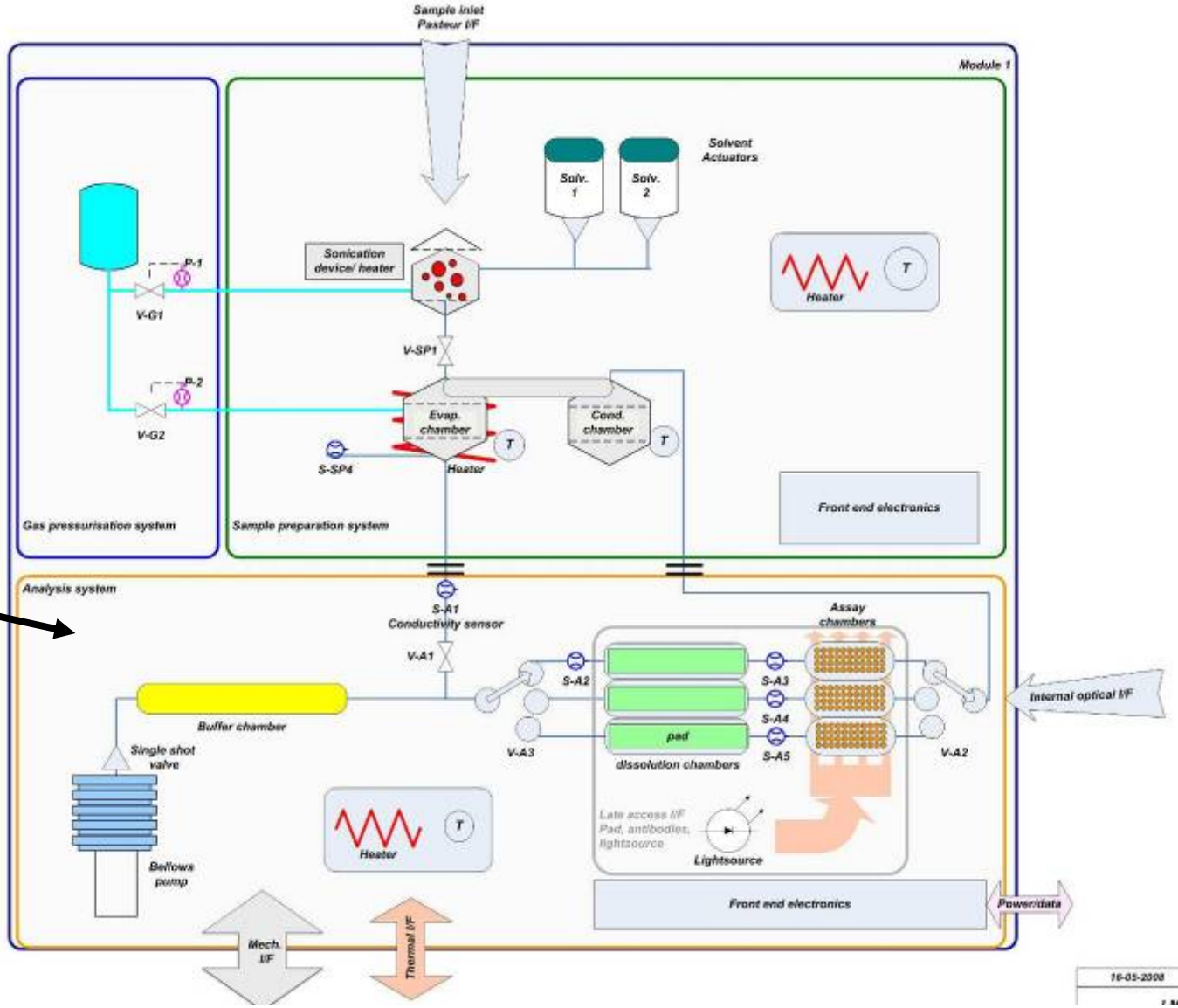
LMC fluidics

LioniX and Dutch Space provide the Analysis Sub-System as the Dutch contribution to the Life Marker Chip instrument



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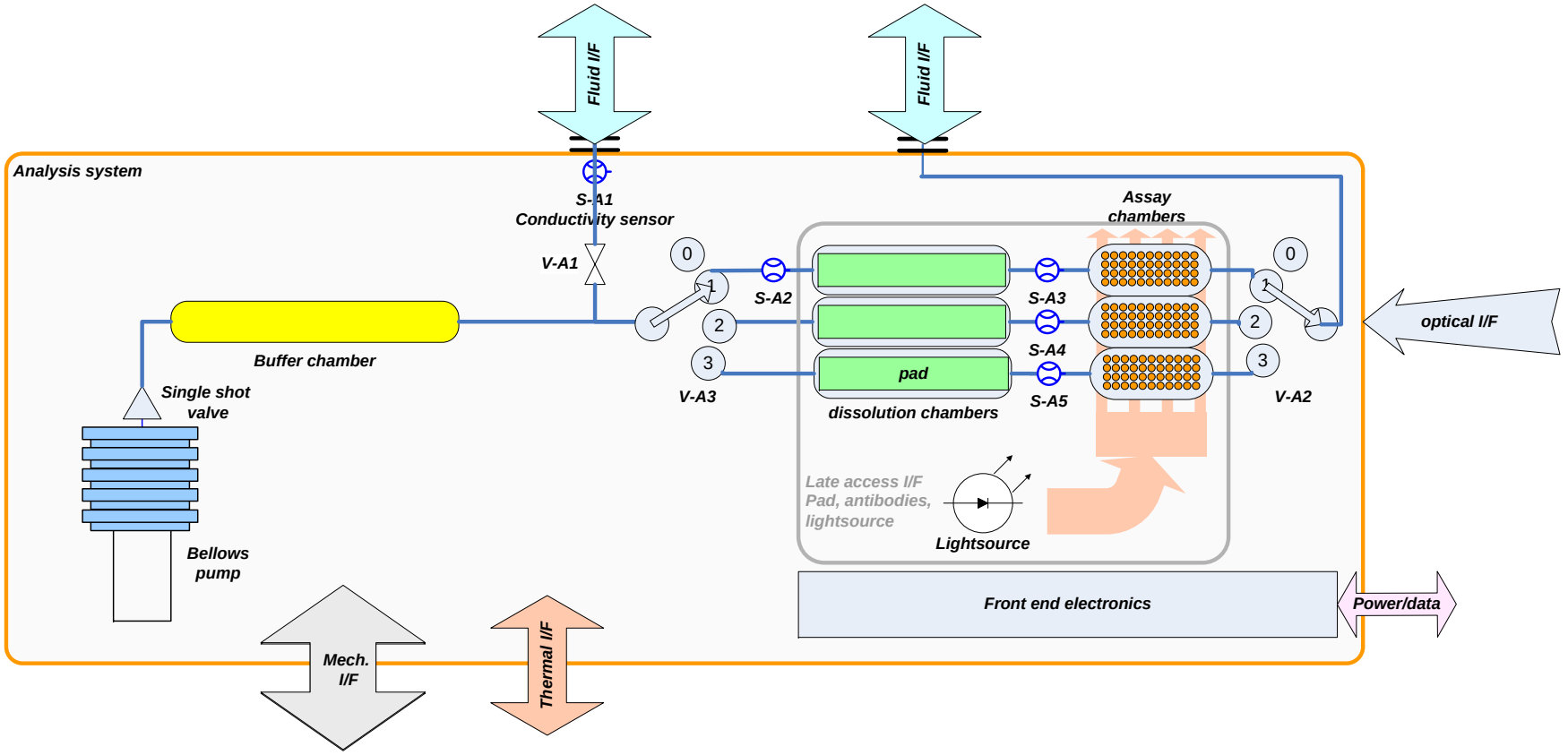
LMC Analysis subsystem fluidics



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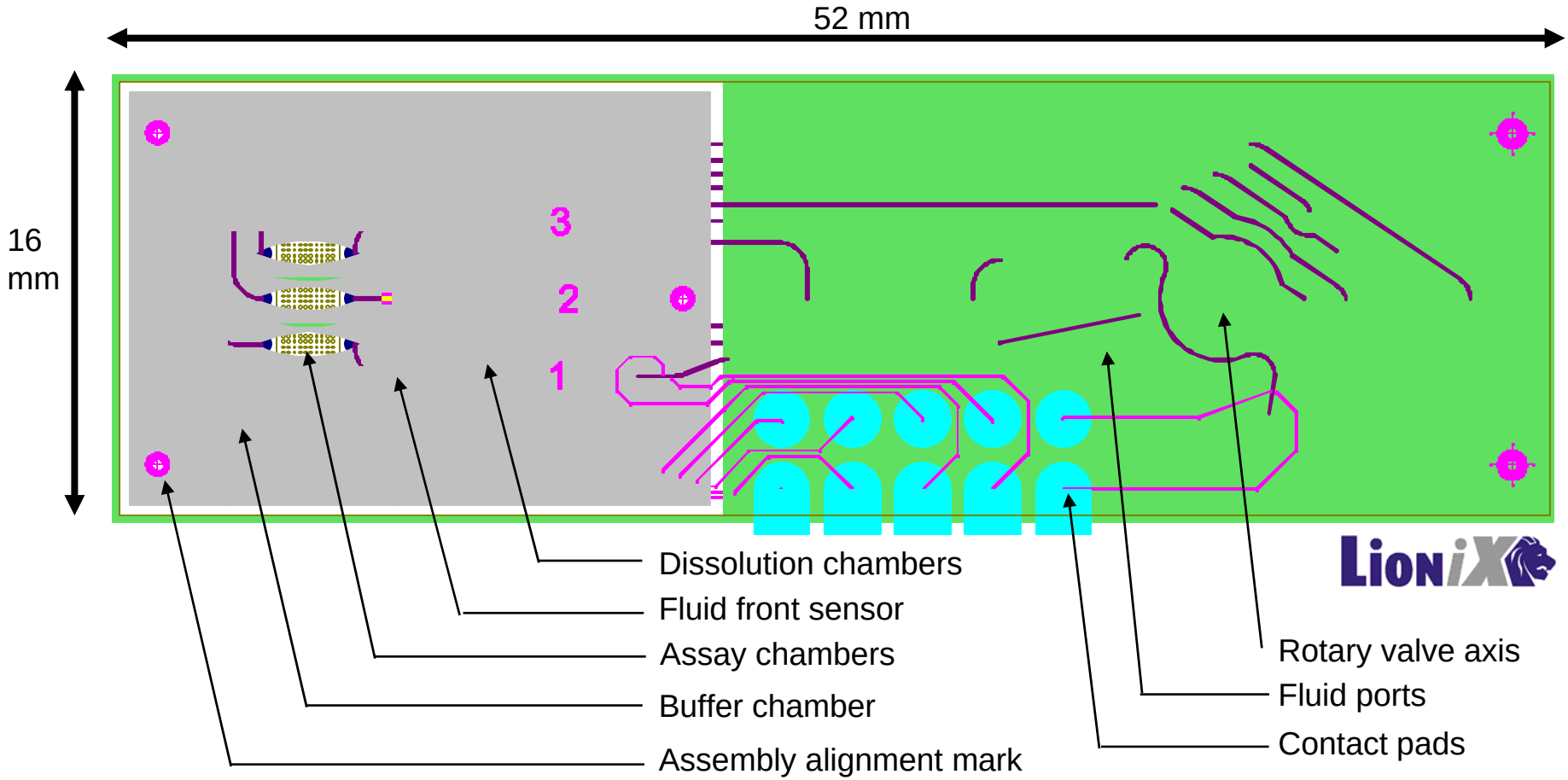
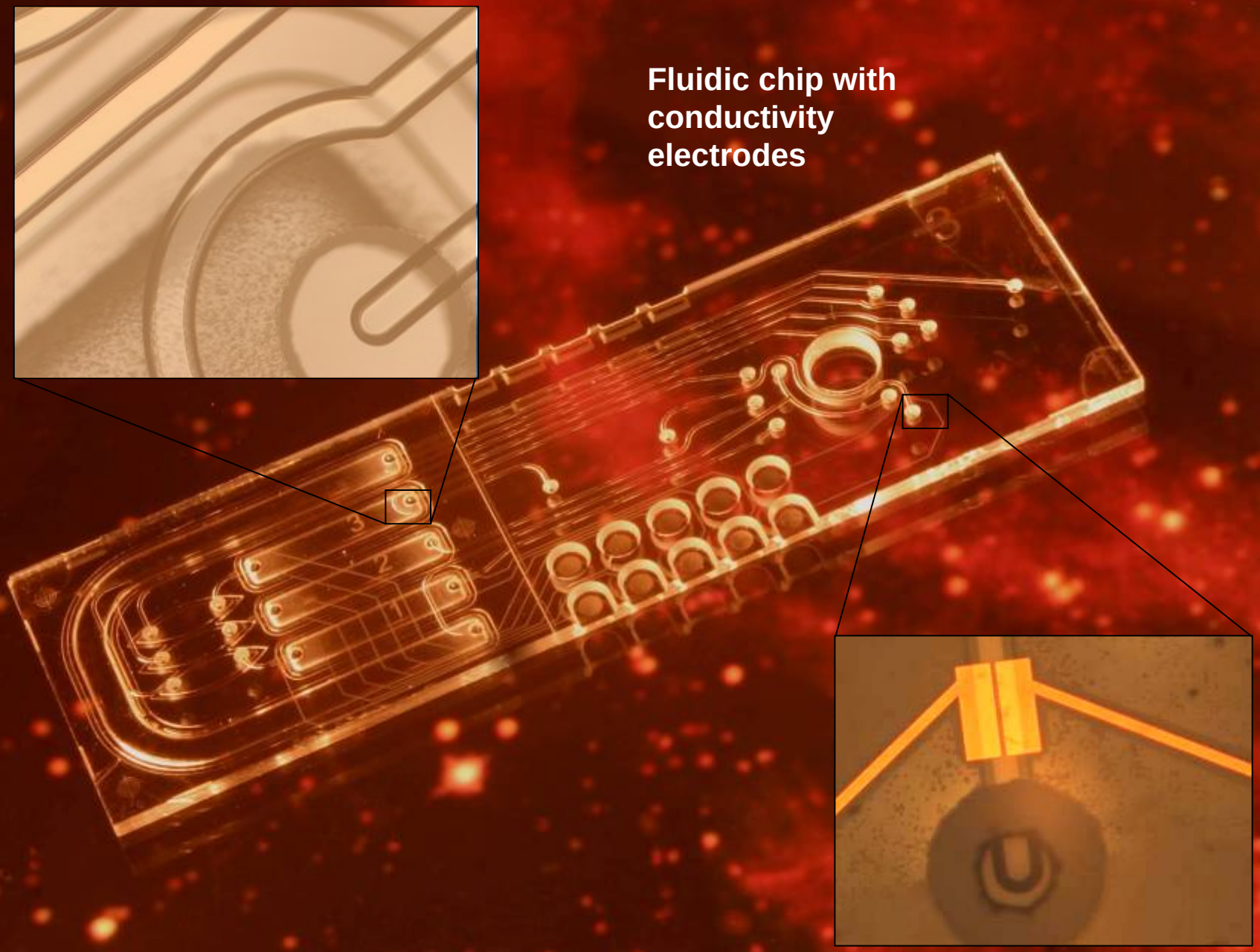
The fluidic chip




Fluidic chip with
conductivity
electrodes

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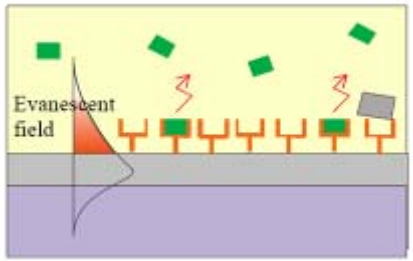
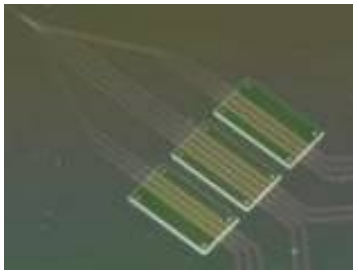
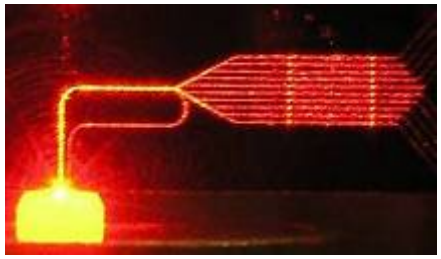
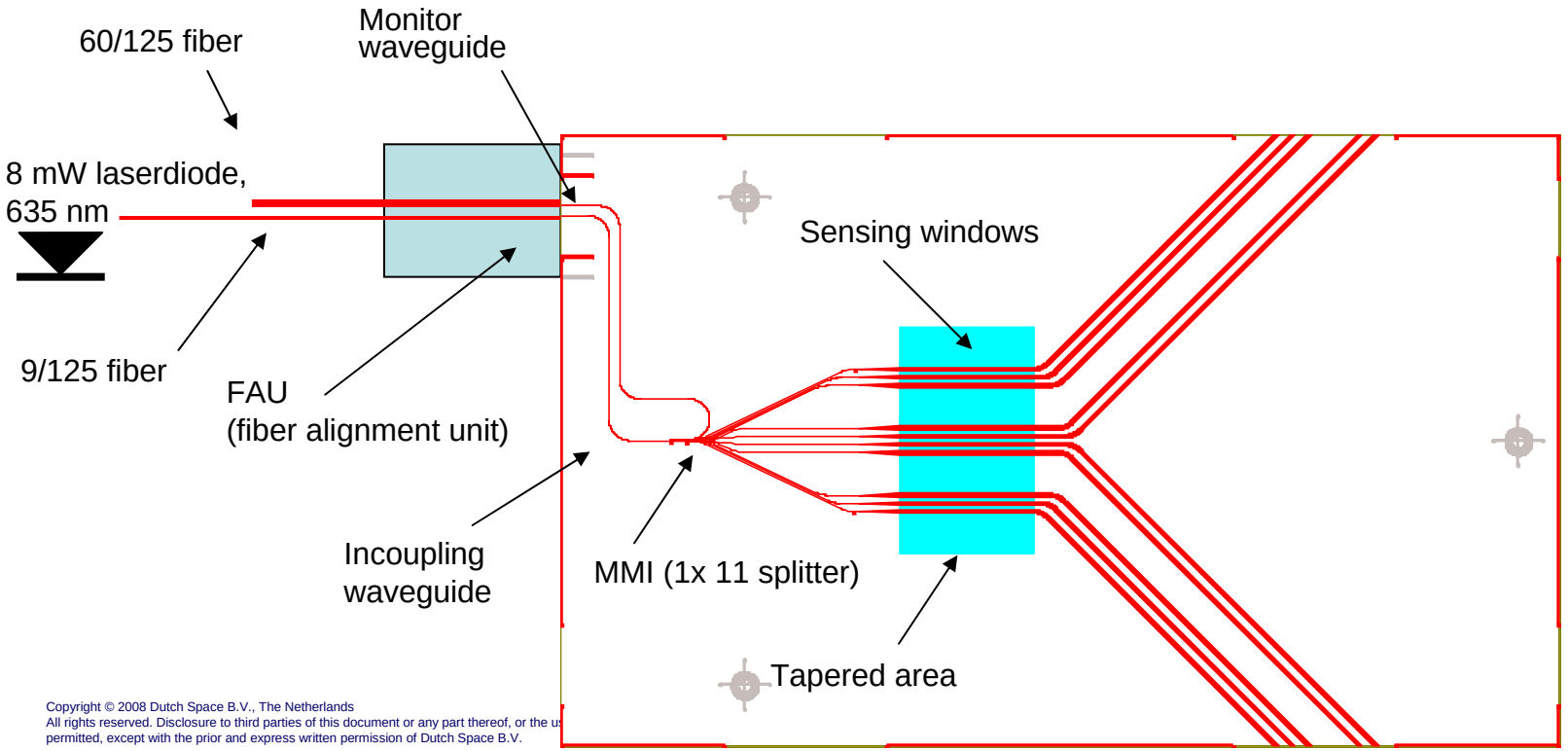
The optical chip









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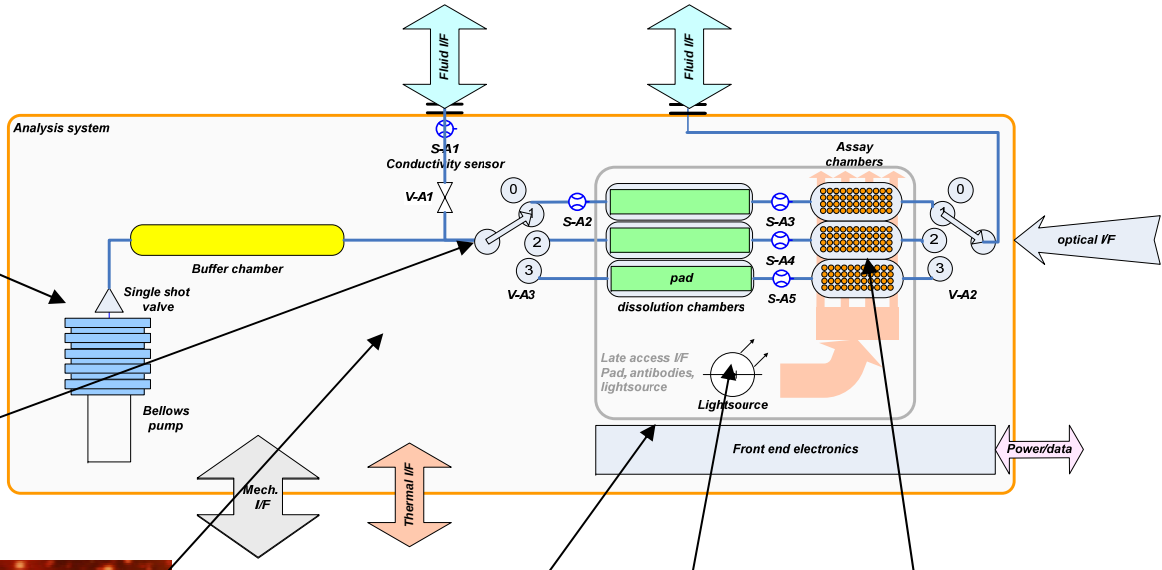
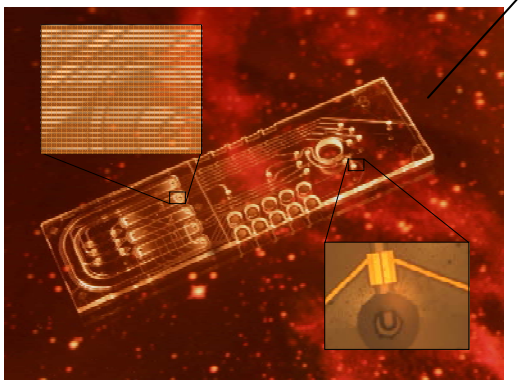
Integration of the chips to a functional system

LMC Analysis Subsystem Elements

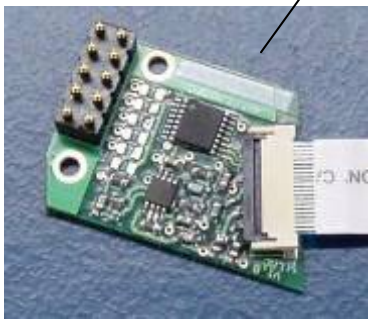
Fluid storage, valve and pump



Rotary valve to control the fluid over the chip

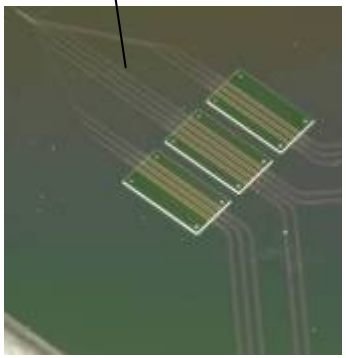


Glass chip with integrated fluid channels, chambers and sensors



Electronics to read out the sensors

Laser



Waveguides to illuminate the attached antibodies

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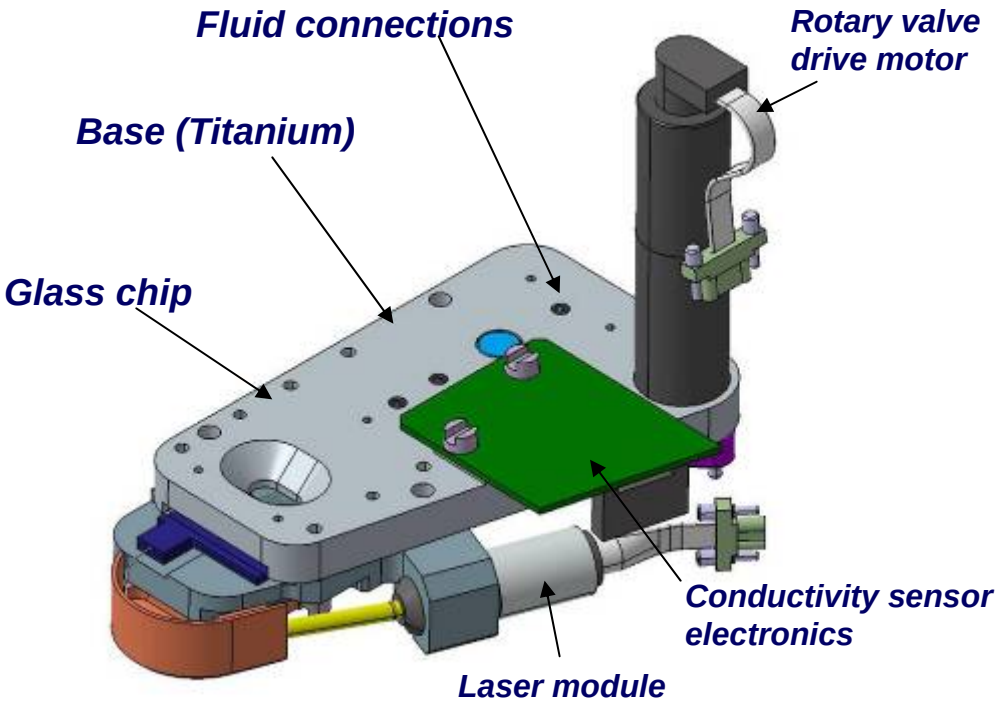
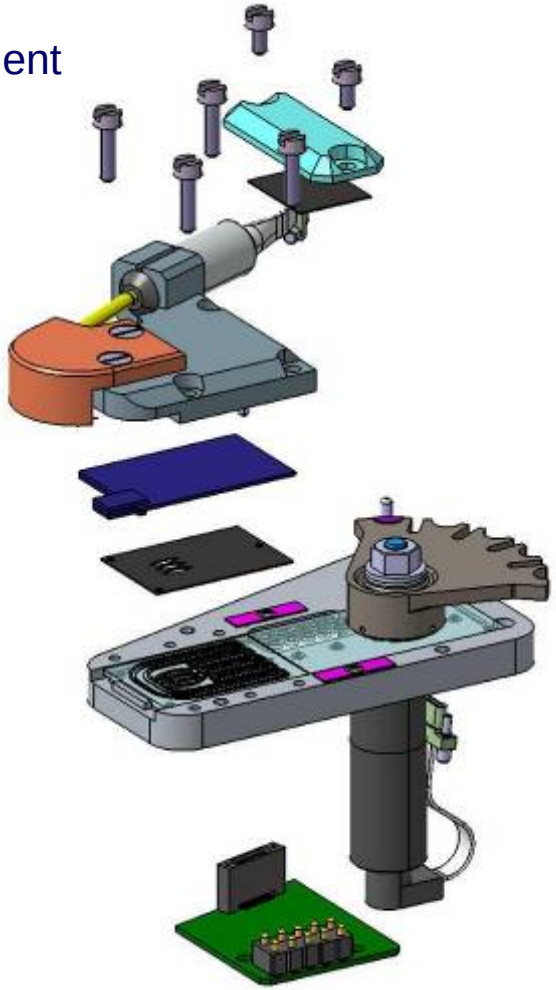
Integration of the chips to a functional system

Packaging of the chips is required:

- to protect the chip from the launch and shock environment
- apply pressure required for leak tightness
- allow control and interfacing with the LMC instrument





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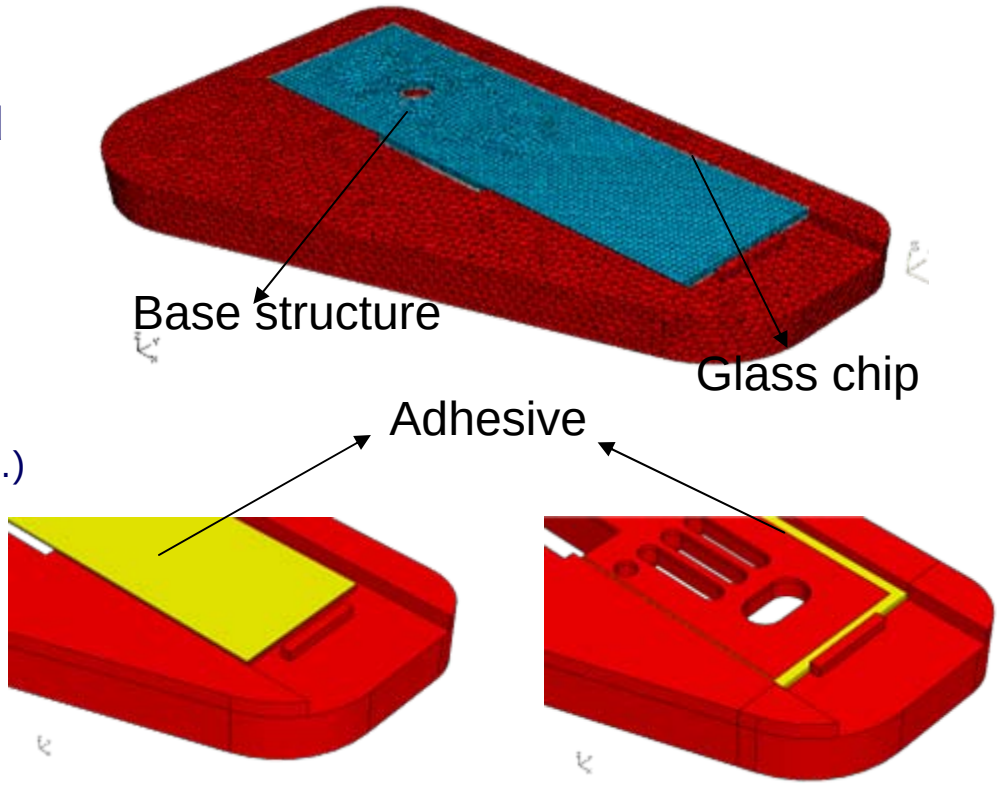
Analysis S/S Structure and Mechanisms

Base Structure/Chip I/F bonding

- The glass chip is to be aligned and secured w.r.t. the base structure
- To determine the best I/F configuration for base structure and glass chip Thermo Structural Finite Element Analysis of the LMC Analysis S/S have been performed
  - Non-linear thermo-structural analysis
  - Loads
    - Thermal loads (autoclave, cruise, …)
    - Bolts/valve pre-tension
  - Cohesive elements (flexible adhesive versus rigid adhesive)
  - Face adhesive versus edge adhesive



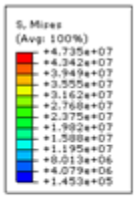
Analysis S/S Structure and Mechanisms (9)

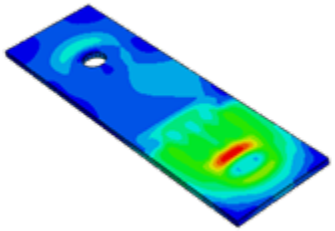
Base Structure/Chip I/F bonding

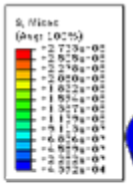
Load cases		RTVS691 Von Mises [MPa] Autoclave	RTVS691 Von Mises [MPa] Room temperature	RTVS691 Von Mises [MPa] Interplanetary cruise phase	STYCAST Von Mises [MPa] Autoclave	STYCAST Von Mises [MPa] Room temperature	STYCAST Von Mises [MPa] Interplanetary cruise phase
Face adhesive	Base	23	216	218	104	213	170
	Glass	20	57	44	101	23	81
	Adhesive	0.2	3.2	4.4	4.7	2.7	9
Edge adhesive	Base	273	204	177	270	201	177
	Glass	47	34	40	76	31	67
	Adhesive	0.2	0.04	0.7	46	10	75

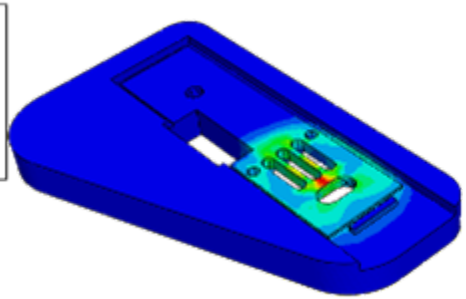
Table 5-1: Summary of maximum von Mises stress in different parts for different configurations of adhesive

Flexible (RTVS691) / edge adhesive is preferred since the stress in the adhesive and glass is relatively low









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Bellows pump design (1)

The following fluid pump design considerations have been derived from the Technical Requirements Specification :

1. Full metal cartridge containing the fluid no elastomeric seals
2. Reliable valve to function after cruise phase
3. Construction that allows thermal expansion / liquid freeze and thaw cycles
4. Accurate pumping behavior (µL/minute)
5. No stick slip effects during pumping
6. One pump for each module, therefore small enough to allow modularity

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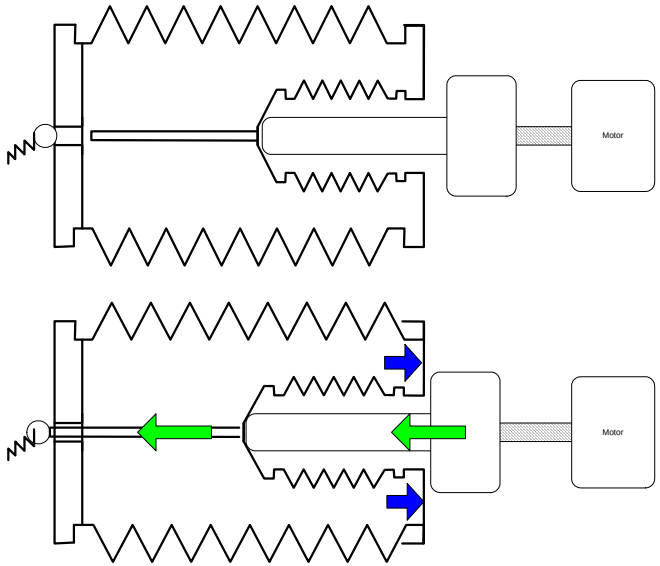
Bellows pump design (2)

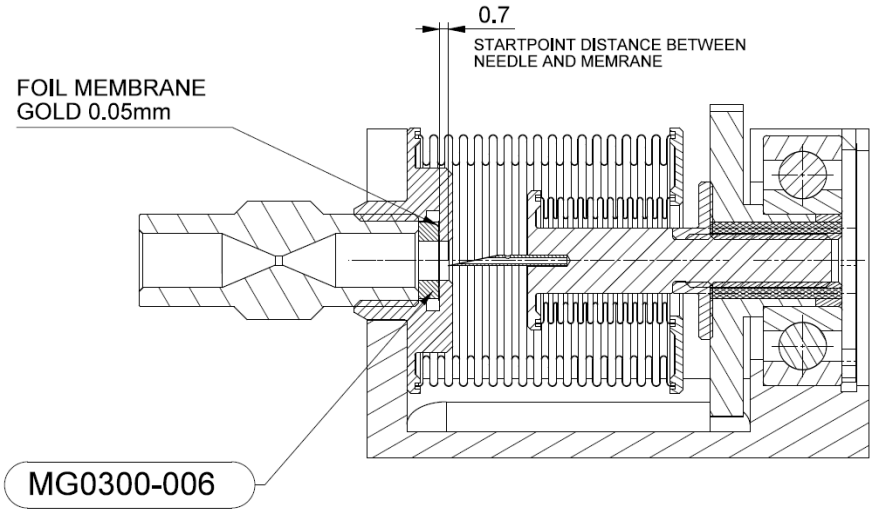
Syringe pump Lab model

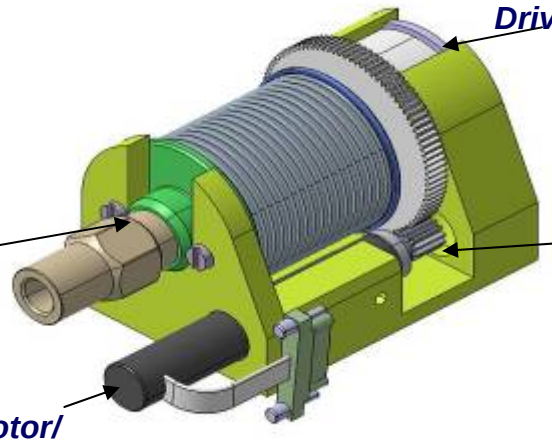
Bellows pump BB



Bellows pump combined with valve

Bellows pump design (3)





Drive spindle pitch 0.7 mm

Fluid I/F and foil membrane

Drive motor gearbox 221:1

Drive motor/ encoder ø6 mm

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Breadboard hardware

The LMC Analysis
Subsystem demonstrator

Currently the system is tested with antibody assays and test samples by the University of Cranfield

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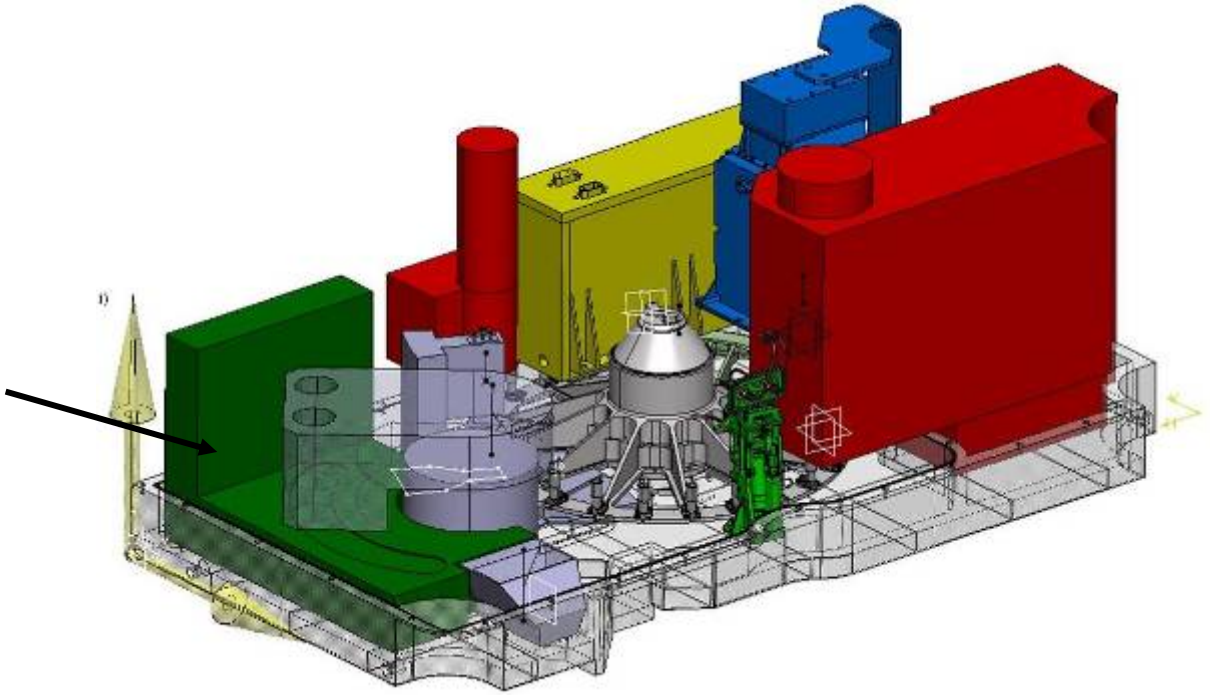
Further work

The envelope available for the LMC instrument has been drastically changed

A study is currently performed to verify if the LMC can be accommodated in the available envelope

LMC envelope



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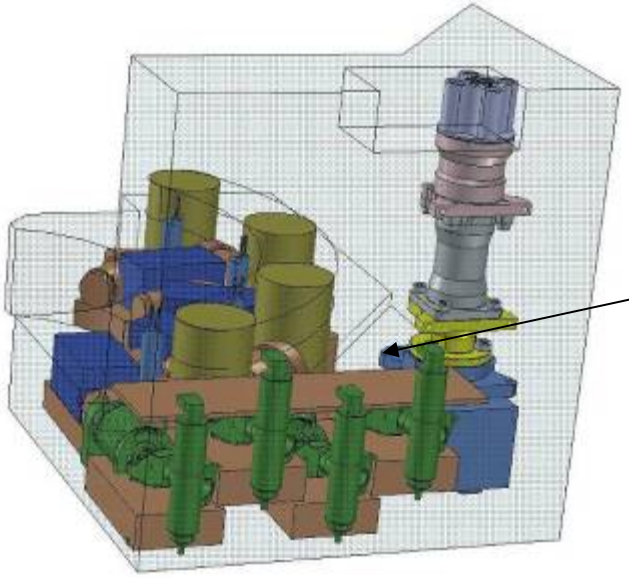
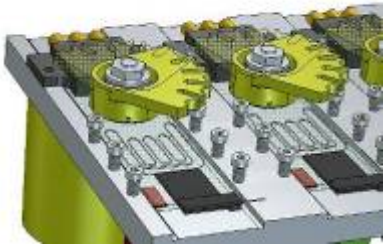
Further work

Transfer the available technology to an even smaller scale instrument package fitting in the new envelope



Conceptual LMC instrument in new envelope

Analysis subsystem concept (11 x 8 x 6,5 cm [3])



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Further work

- A concept is drawn for a new configuration fitting the envelope
- In the coming year towards the planned delta-PDR (2011) we have to prove that we can build a working analysis system, surviving also the simulated launch, cruise and operational environment to which the system will be exposed
- Planetary protection is to be applied according to COSPAR regulations, this requires aseptic integration of the LMC
- The LMC flight instrument has to be delivered in 2014