University of Leicester

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7th China-UK Workshop Space Science & Technology
Kents Hill Park Conference Centre, Milton Keynes
31st August to 1st September 2011

The Life Marker Chip (LMC) experiment on ExoMars

David Cullen & the LMC Consortium

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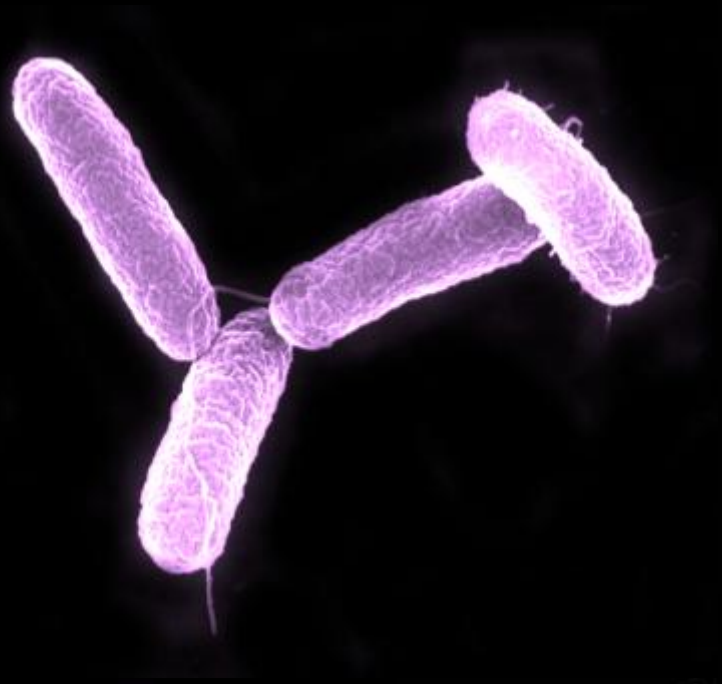
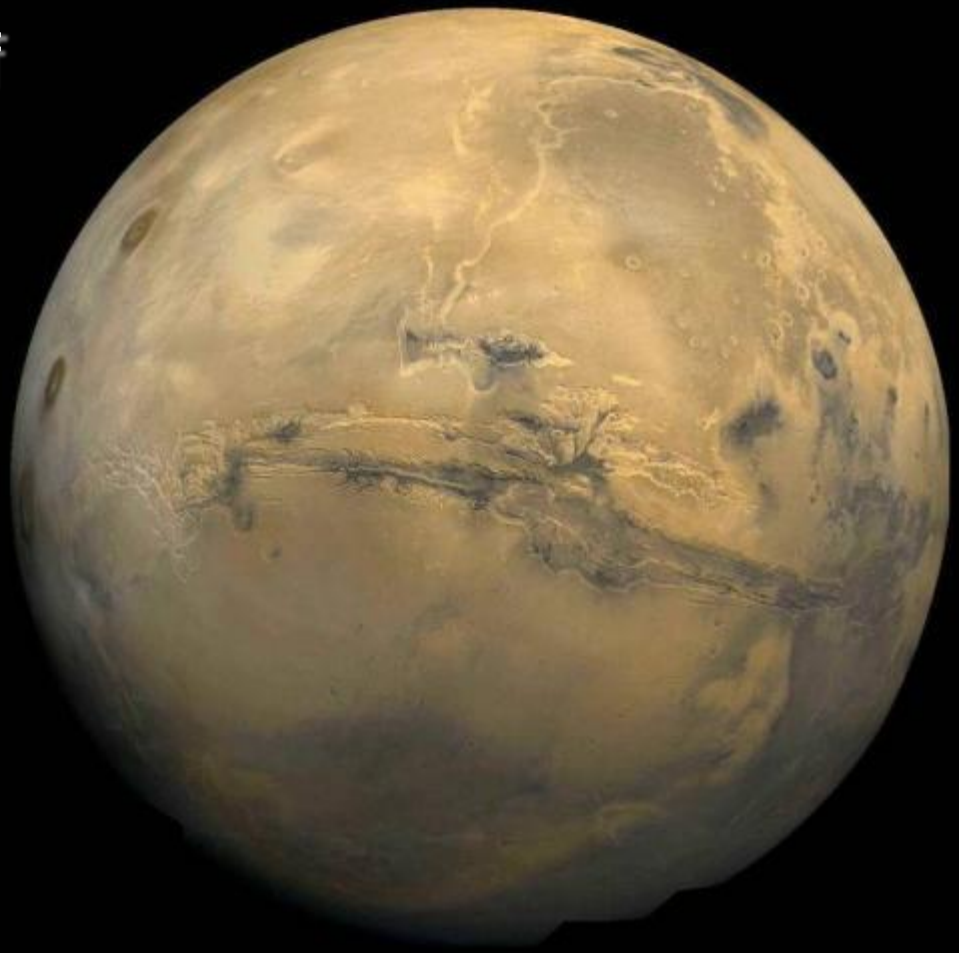
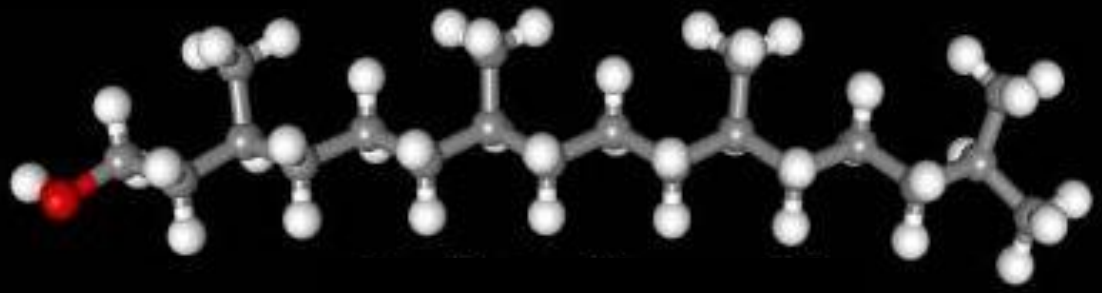
http://www.cranfield.ac.uk/health/abouttheschool/people/page8056.jsp

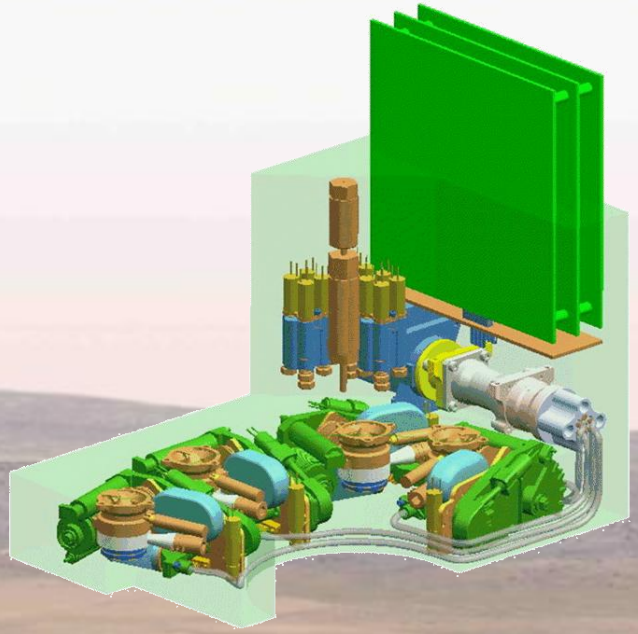
How to detect evidence of Life in on Mars?







ESA's ExoMars rover
(CGI version 2010)



Life Marker Chip
Flight Model design
(early 2010)

Lateral flow immunoassay
(*e.g.* pregnancy test kit)

Outline

- ExoMars rover mission current situation
- LMC science case & molecular targets
- Overview of LMC instrument
- LMC current status

ExoMars
current status

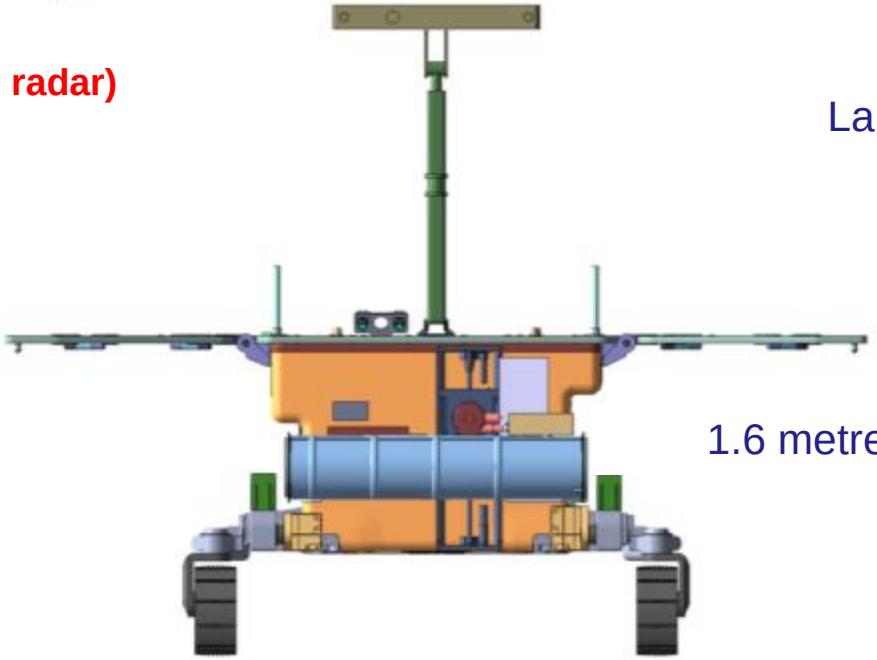
ExoMars Rover (coming into 2011)

Instruments

- PanCam
- **WISDOM (ground penetrating radar)**
- Ma-Miss
- MicroOmega
- **MOMA (GC/LD-MS)**
- RAMAN
- Mars-XRD
- **Life Marker Chip (LMC)**
- CLUPI

Other features

- **Drill (to ~2m)**

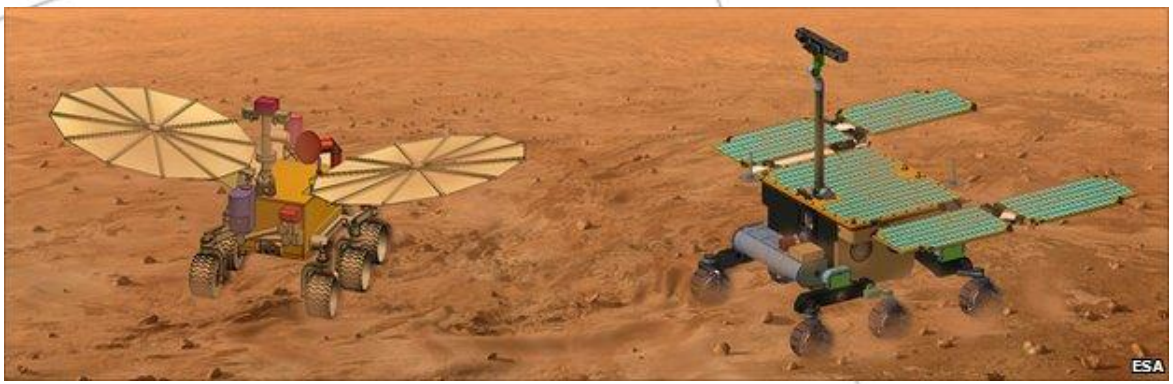


Launch scheduled for 2018

1.6 metres tall

ExoMars – into 2011

- **Joint Mars Exploration Programme (JMEP) between NASA and ESA**
  - **2016 ExoMars mission – orbiter and ESA EDL demonstrator**
  - **2018 ExoMars mission – dual rover ESA ExoMars and NASA MAX-C delivered by modified NASA Sky Crane EDL**



- **Spring 2011 - cost concerns in ESA and NASA**
  - **Mismatch between the ESA cost cap, the programme's scope, and its estimated Cost at Completion (CAC)**
  - **NASA technical and budget difficulties to support their commitments for the Joint Mars Exploration Programme (JMEP)**
- **Abandonment of dual rover ExoMars / MAX-C mission**

ExoMars – post April 2011

- Route forward
  - ESA and NASA recommend development of a single rover mission for 2018 launch
  - NASA will provide launcher, cruise stage, and EDL system
  - ESA will provide rover
  - Will accommodate the present ESA exobiology payload (ALD), subsurface drill, and caching system to be provided by NASA
  - Also a robotic arm with mini corer to acquire additional samples and to pass them either to the caching system or to the rover's analytical instruments

- Immediate issue
  - Expected autumn announcement of NASA financial agreement

LMC objectives & targets

LMC Science Objectives

- **Detection of organic molecules in Martian rocks and regolith**
  - Detect organics in suitable samples – *e.g.* sedimentary, evaporite, … deposits – with lower limits of detection at ppm to ppb range
  - Measure organic content versus depth (0m to 2m)
  - Interpret detected organic molecules within categories of extinct and extant life (Earth-like Life), abiotic chemistry
- **LMC organic molecular target classes**
  - Extinct Life – preservation / diagenetic products of ancient life
  - Extant Life – geologically short-lived products of present / recent life
  - Abiotic organics – examples of on-going meteoritic in-fall, preservation / diagenetic products of early Mars organics inventory
  - Spacecraft contamination markers – mainly high-level Earth micro-organism markers
  - Assay control markers – for example synthetic organic molecules

Categories of LMC targets – science & physicochemical

1. **Small apolar acyclic aliphatic**
   - structurally un-constrained, no functional groups
   - maps to extinct life biomarkers
   - examples – phytane, squalane, hexadecane, ...
2. **Small apolar polycyclic aliphatic**
   - structurally constrained, no functional groups
   - maps to extinct life biomarkers
   - examples – 5β sterane, hopanoid, ...
3. **Small polycyclic aromatic**
   - structurally constrained, no functional groups
   - maps to abiotic markers
   - examples – pyrene, phenanthrene, naphthalene, ...
4. **Small polar**
   - Various inc. extant life biomarkers
   - maps to various science targets
   - examples – positive controls, amino acids, various extant life biomarkers, ...

LMC overview

The SMILE / LMC concept

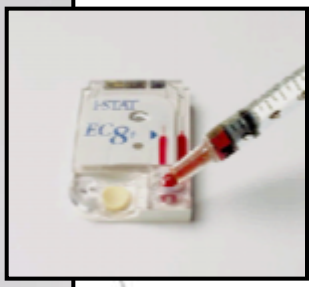
- **Specific Molecular Identification of Life Experiment (SMILE)**
- **… more commonly known as the Life Marker Chip (LMC)**
- Lead by Leicester (M.R. Sims) and Cranfield (D.C. Cullen) universities
  - initial thoughts 1998
  - proposal to ExoMars mission / ESA 2003
  - selected for initial development 2006
  - launch scheduled for 2018 (instrument delivery 2014)
  - exploitation of recent developments in biosensor & bio-analytical technologies
- For planetary exploration and terrestrial applications

LMC overview

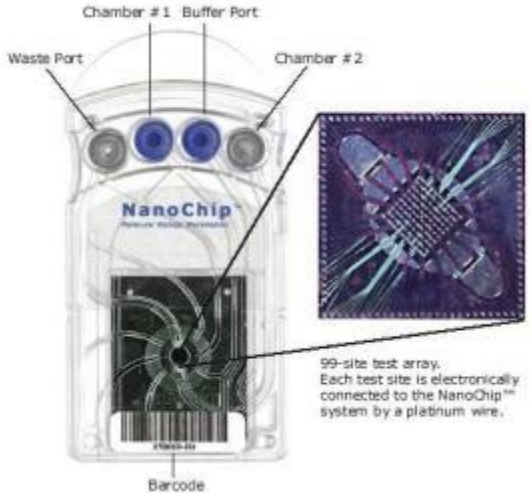
- **Each sample approx 1g crushed Martian sample (drill core) from ExoMars SPDS (sample processing and distribution system)**
- **LMC has four single-use analysis modules – each able to analyse one Martian relevant sample**
- **Each module performs**
  - Organic molecule extraction into liquid solvent
  - Analysis of liquid extract by **multiplexed** immunoassay
  - Multiplexed immunoassay has up to 25 different assay – i.e. can detect up to 25 different targets (target classes) per sample
  - All modules to have same extraction conditions and immunoassays (baseline)
- **Internal LMC conditions maintained >> 0°C and >> 200mbar**

Examples of commercial biosensor / array technologies

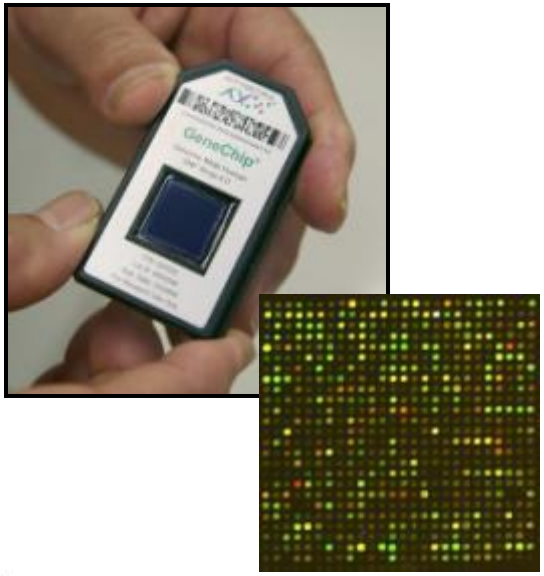
Glucose biosensors



Multi-analyte point-of-care clinical analysers



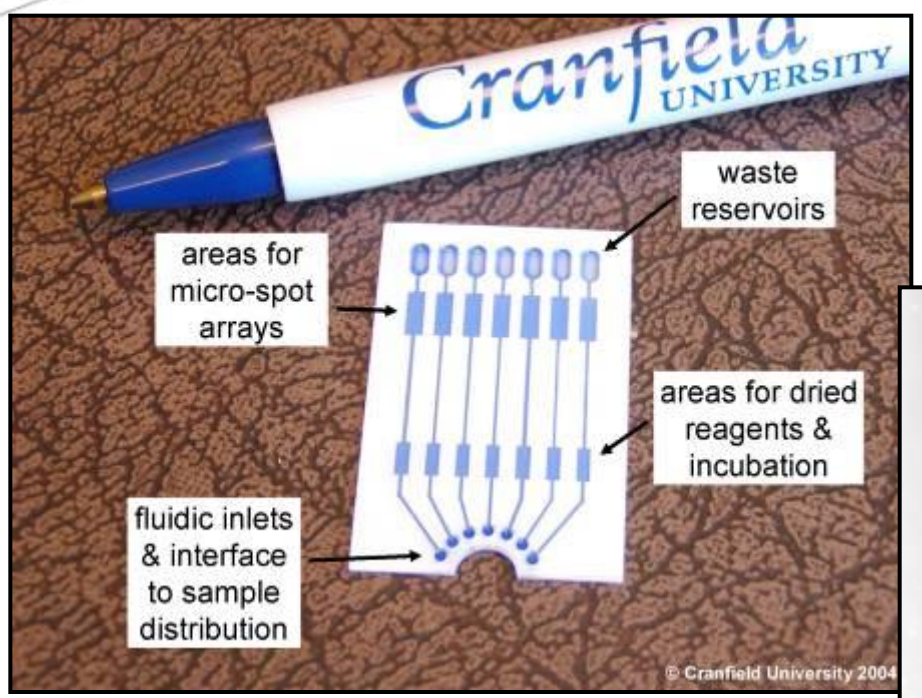
Pregnancy tests
(lateral flow immunodiagnostic)

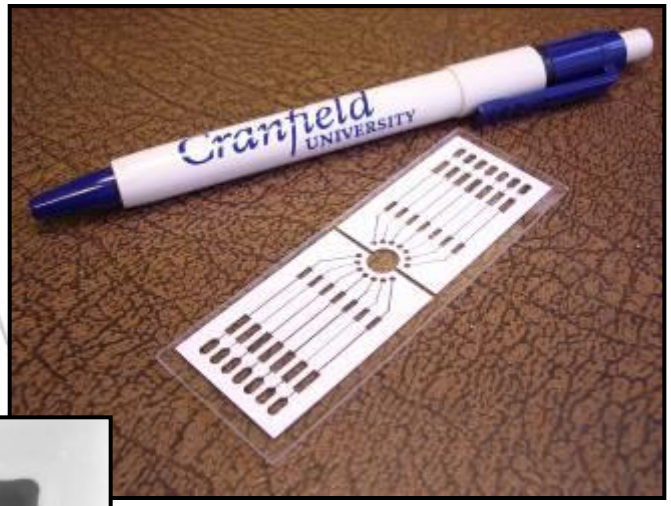


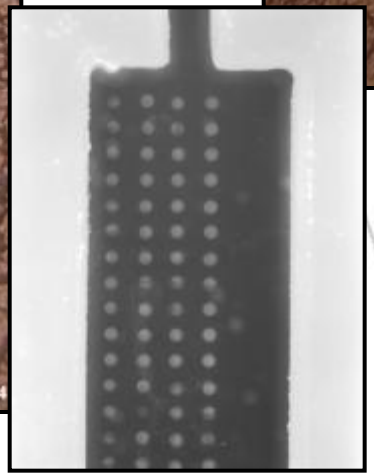
DNA and protein microarrays

Example of micro-fluidic assay device

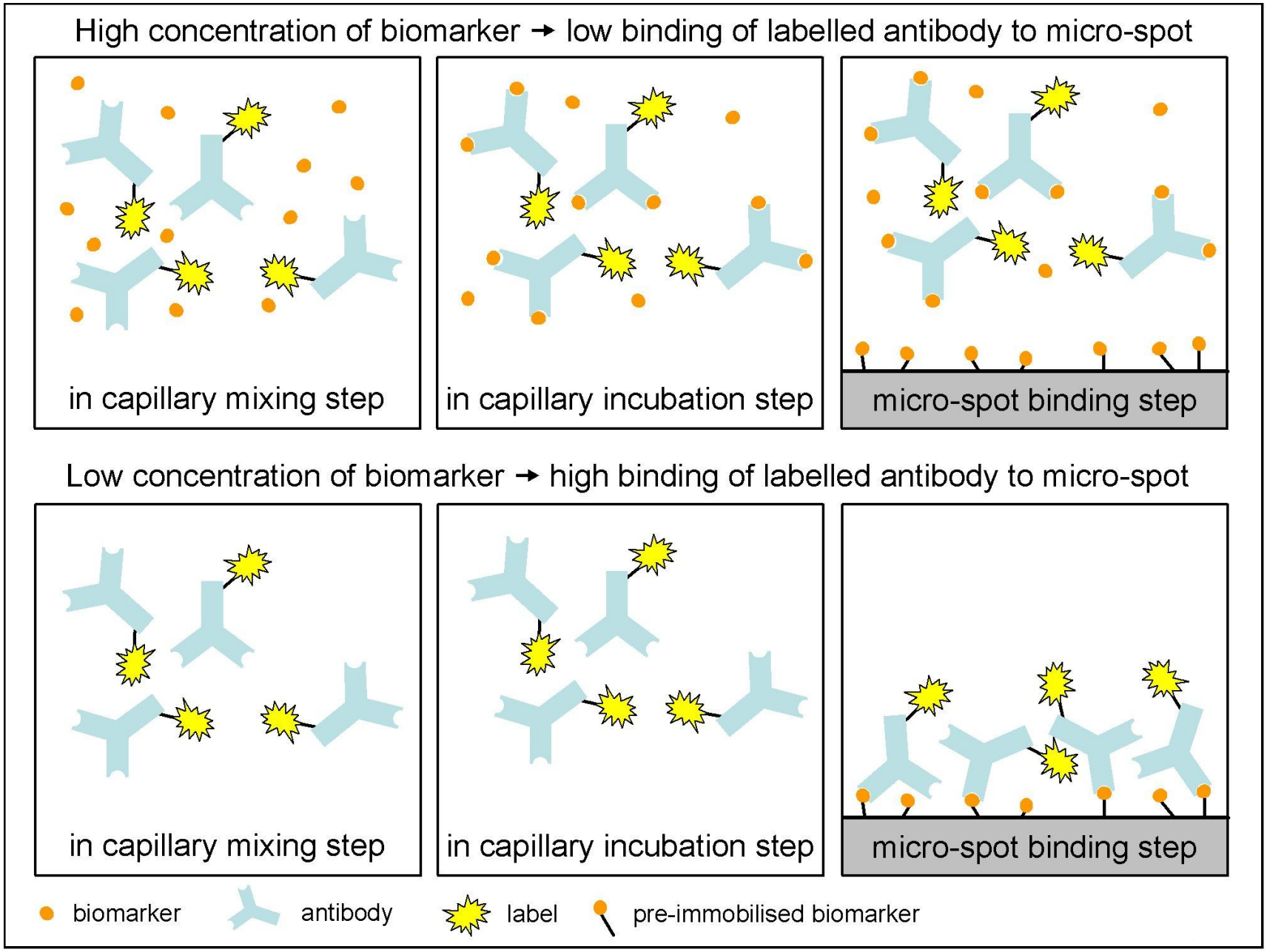
- Multiplexed micro-spot immunoassay arrays (~100 spots / ~25 assays per channel)
- Multiple single-use µ-fluidic channels (*circa* 2004)
- Real-time optical evanescent readout using fluorescent labelled reagents
- Lateral flow immunodiagnostic approach
- “Hi-tech pregnancy” test







Schematic of micro-spot inhibition immunoassay format



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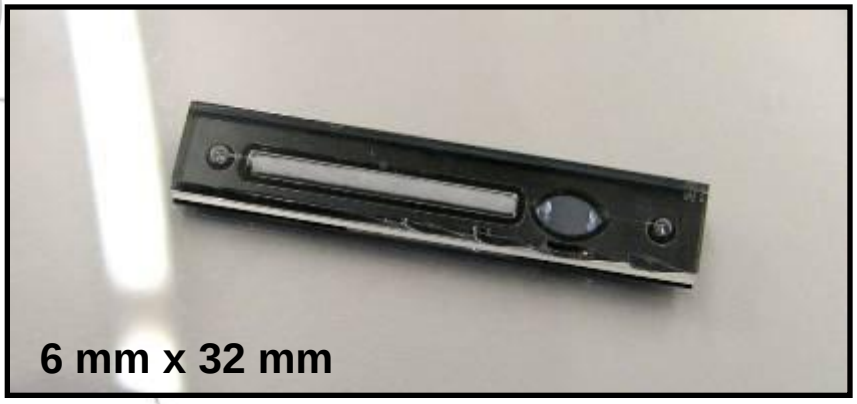
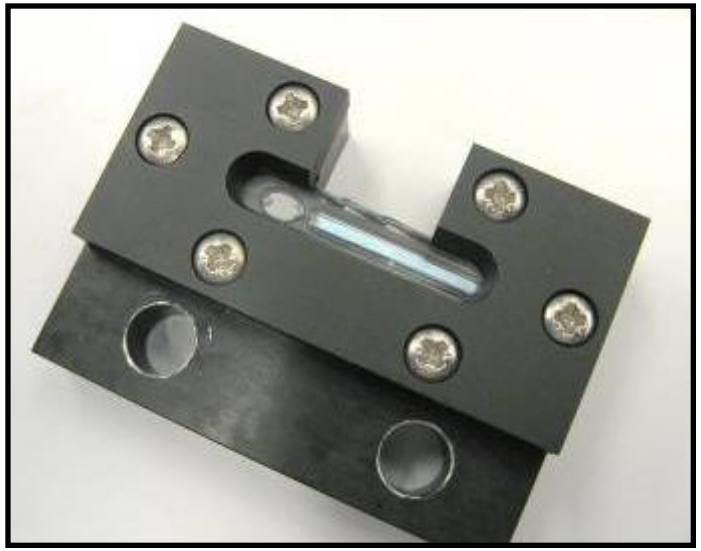
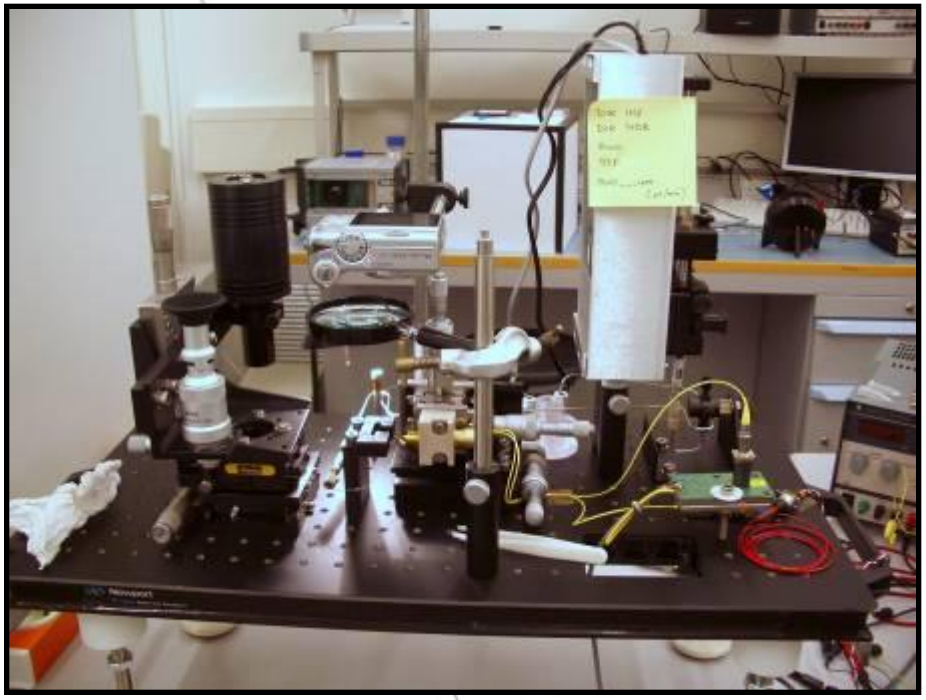
Examples of current LMC assay breadboard components (circa 2009)

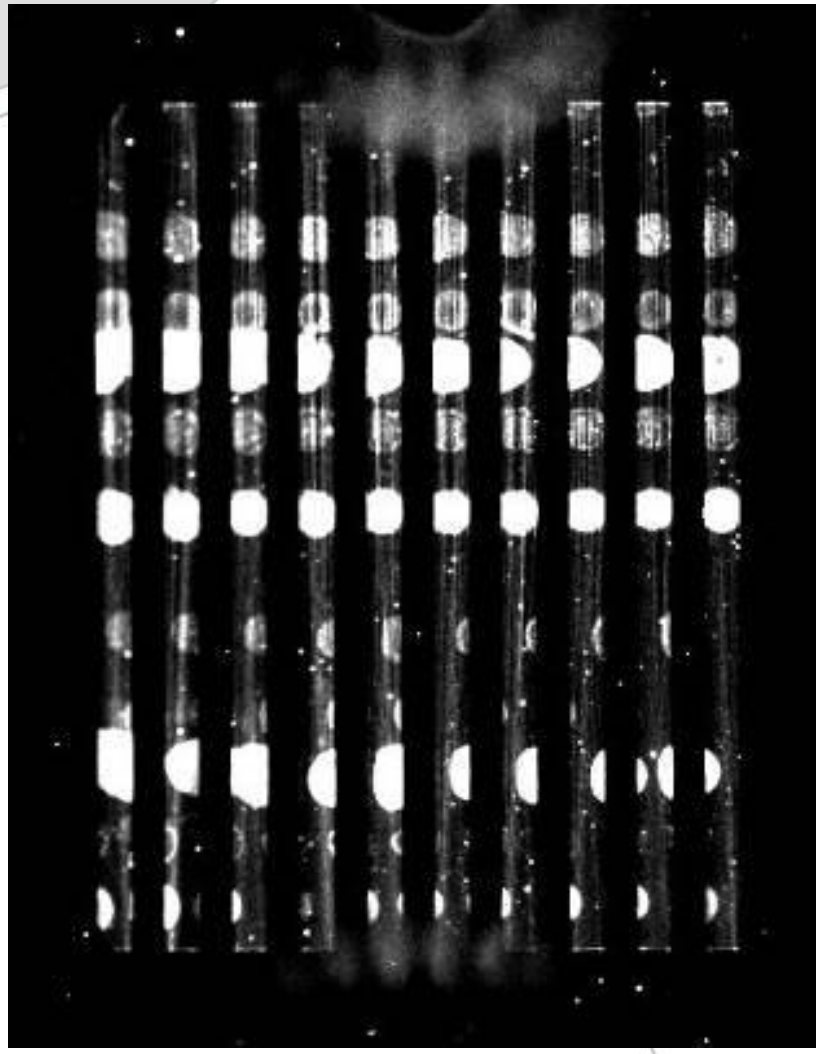






After assay image of optical waveguide LMC device showing multiplexed antibody binding

LMCv1[2,7] W312 after x0



OWG images taken with the ABB after an assay containing atrazine, GroEL, phytanic acid and PAH antibodies

Design for the Life Marker Chip (LMC) Flight Model (FM) (*ca.* early 2011)

esa

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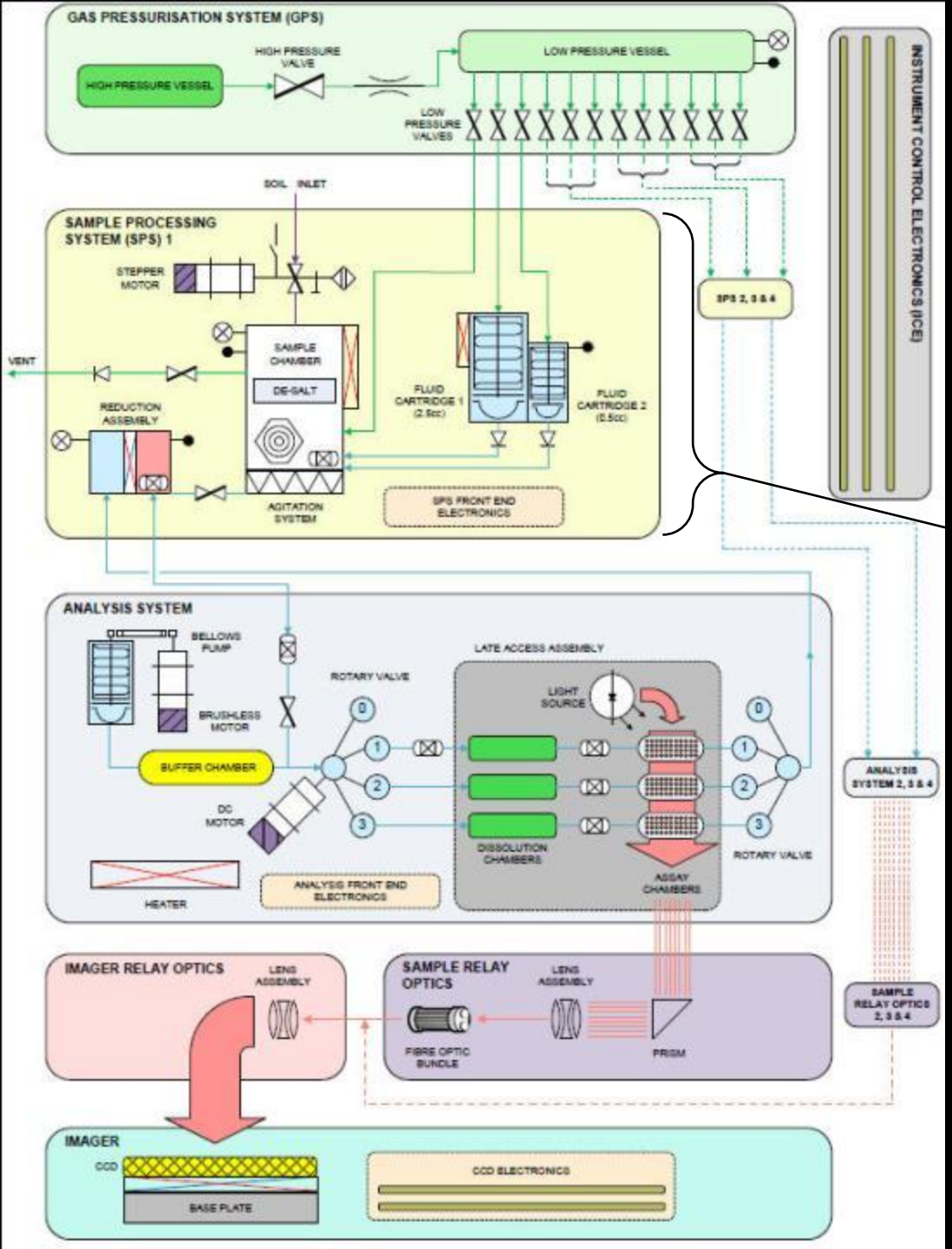
Life Marker Chip (LMC) Function Breakdown Model



Sample extraction

Analysis (multiplexed immunoassay)

Optics – imaging of the multiplexed immunoassay

LMC current status

LMC development on-going

- Immunoassay library development
  - Phage-display recombinant antibody development
  - Traditional antibody development / procurement
  - Integration of antibodies into LMC assay hardware
- Sample extraction development
  - Solvent extraction compatibility with diverse polar / apolar target extraction, matrices & antibody assays
  - Use of Martian sample analogues
- Flight hardware development
  - Flight model design
  - Accommodation within rover payload / ExoMars Analytical Drawer (ALD)
- Planetary protection & contamination control (PP&CC)
  - Cleaning, sterilisation and validation
  - PP&CC integration in FM assembly, test and verification (AIV)

Acknowledgements (major partners)

... plus many others

HAM•E
Hypervelocity Artificial Meteoroid Experiment

A mission concept

Hypervelocity Artificial Meteoroid Experiment

http://www.cranfield.ac.uk

Questions