A snapshot on Cubesat related activities, perspectives for Astrobiology/ Astrochemistry in ESA

Robert Lindner, ESA-Directorate of Technical & Quality Management
Roger Walker, ESA-Directorate of Technical & Quality Management
ESA/ESTEC

Andreas Elsaesser, Universiteit Leiden
Pascale Ehrenfreund, Universiteit Leiden
1. IOD missions in development
2. Current Status of European Astrobiology/Astrochemistry activities, experiments under implementation on ISS
3. Currently planned CubeSat experiment with ESA for Astrochemistry
4. Future perspectives for Astrobiology/Astrochemistry
5. Conclusion
IOD MISSIONS IN DEVELOPMENT
SIMBA IOD Mission

- Contractor: Royal Meteorological Institute and KU Leuven (Belgium)
- Sun-Earth radiometric science demonstrator:
  - Measure the Essential Climate Variables of Total Solar Irradiance, Earth Radiation Budget and Sun-Earth radiation imbalance
  - Payload: absolute cavity radiometer (RMI), 3-axis ADCS with star tracker (KUL)
  - Platform: 3U CubeSat (ISIS)
  - Heritage: Sova-P instrument on CNES Picard mission; Diarad on SOHO
  - Launch on QB50 flight in 2016 to 380x700 km altitude, 98° inclination

Status: PDR in June 2014
QARMAN IOD Mission

- Contractor: Von Karman Institute (Belgium)
- Atmospheric re-entry demonstrator
  - New heat shield materials -> ablation, plasma field measurements
  - Aerodynamic drag augmentation and passive attitude stabilisation system
  - Telemetry data relay system during re-entry via the Iridium constellation
  - Launch on QB50 flight in 2016 to 380 km altitude, 98° inclination
  - Platform: custom, subsystems from various suppliers

Status: PDR in June 2014
PICASSO IOD Mission

- Belgian Institute of Space Aeronomy, Royal Observatory Belgium, VTT Finland
- Atmospheric chemistry science demonstrator
  - Stratospheric Ozone distribution -> limb sounding of solar disk with multi-spectral imager
  - Mesospheric Temperature profile -> multi-spectral imager (VTT)
  - Electron density in the ionosphere -> multi-Needle Langmuir Probe
  - Earth Radiation Budget -> micro-bollimetric oscillation system
  - Platform: 3U CubeSat (Clyde Space)
  - Launch on QB50 flight in 2016 to 380x700 km altitude, 98° inclination

Status: PDR in November 2014
GOMX-3 IOD Mission

- Contractor: GomSpace (Denmark)
- 3U CubeSat telecommunications payload demonstrator
  - Improved Detection/de-coding of ADS-B signals broadcast by aircraft
  - Characterisation of Spot beams broadcast by GEO telecom satellites
  - Primary Payload: L-band Reconfigurable Software Defined Radio receiver
  - Additional payload: 3-axis ADCS with IR horizon sensors for nadir pointing accuracy of ~1° (day/night operation)
  - Launch to ISS via GomSpace/NanoRacks in July 2015
  - Deployment during Short Duration Mission of ESA astronaut Andreas Mogensen

Status: CDR in July 2014
CURRENT MISSION STUDIES
**Active Debris Removal IOD Mission**

- **Contractor:** Swiss Space Center, EPFL
- **Objective:**
  - IOD and operational validation of critical ADR technologies at sub-scale for future use on full-scale missions to remove large debris objects
- **Mission concept #1:**
  - Rendezvous sensors (Flash Lidar, VIS & IR cameras)
  - Motion reconstruction of uncooperative target
- **Mission concept #2:**
  - Net capture system dynamics & target interaction
  - Coupled two-body tether dynamics and control
- **System concept:**
  - 8U Chaser satellite + 4U Target satellite
  - Coupled together and launched in 12U deployment system
  - Low velocity mutual separation after LEOP
  - Close proximity ops with 6 DoF chaser around “passive” target with settable attitude rates

**Status:** study completion July 2014
CubeSat Mission Applications

• ARTES 1 study “Nano-satellites for Commercial Telecommunication Services”
  ➢ Open competitive Invitation To Tender (now closed)
  ➢ Any revenue generating service from telecom (e.g. M2M, signal detection, frequency monitoring etc)
  ➢ Assessment of technical feasibility and commercial viability of selected concepts
  ➢ Single nano-satellites or nano-satellite constellations
  ➢ CubeSats or other form factors up to 12U/16 kg

• GSP SysNova Study “Remote Sensing with Multiple Cooperative Nanosats”
  ➢ Open competitive Invitation To Tender (closes 1 August)
  ➢ Award of up to 6 parallel studies
  ➢ Evaluation of studies and selection of a winner
  ➢ Prize: Phase 0 study in the ESTEC Concurrent Design Facility
  ➢ Challenges: Land (optical), Atmospheric Chemistry (optical), Weather (RF)
  ➢ High spatial or temporal resolution enabled by constellations or swarms
  ➢ CubeSats or other form factors up to 20 kg, system ROM cost <60 MEuro
Current Status of European Astrobiology Activities

• There is an active Astrobiology / Astrochemistry community in Europe, with strong links to research groups outside of Europe
• Several short and long duration flight experiments have been performed with dormant micro-organisms & small animals, as well as organic chemistry experiments
  • Foton-Biopan (6 missions)
  • Foton-Stone (2 missions)
  • ISS-EXPOSE (2 missions, one in preparation)
• Many supporting ground studies in simulated space and analogue environments
• The results of many of these studies have been published and allow an assessment of the survival of micro-organisms in the harsh environment of space

3rd Interplanetary CubeSat workshop, Pasadena
Experiments under implementation on the ISS

- **EXPOSE-R2**
  - Reuse of EXPOSE-R facility to perform three astrobiology / astrochemistry experiments
  - Launch to ISS planned in Mid 2014, external deployment nominal 18 month mission

- **OREOCUBE**
  - Follow on to OREO/S Cubesat
  - In-situ measurement of organic chemistry processes by UV/visible spectroscopy
  - Launch to ISS ~2016, external exposure and retrieval for postflight analysis of samples after several months

3rd Interplanetary CubeSat workshop, Pasadena

[Image of EXPOSE-R2]

[Image of OREOCUBE]
• Proposed to the International Research Announcement for Research in Space Life Sciences ILSRA 2009 and selected for Definition Phase by the European Space Agency (ESA)

• OREOCUBE leverages the payload SEVO (Space Environment Viability of Organics) of NASA’s O/OREOS Nanosat, a 10-cm cube containing a highly capable UV-visible spectrometer and 24-sample carrier

• The experiment technology can effectively measure the degradation of organic samples, thereby providing greater insight into the kinetic details of the photochemical reactions
OREOCUBE on the ISS (2016?)

1. OREOCUBE proposes the development of 2 integrated “single-cube” UV/visible/near-IR spectroscopy systems

2. OREOCUBE can simulate planetary micro-environments: any gas/humidity composition can be sealed into the individual sample cells

2. OREOCUBE measurements in the radiation environment of the ISS will allow us to better understand the carbon chemistry in space environments, extraterrestrial delivery processes and prebiotic chemistry on the early Earth
Recommendation #1:
- Based on past and current experience, continue to develop new orbital exposure facilities both inside and outside of spacecraft. **Develop systems capable of in situ monitoring of microbial growth in Earth orbit (e.g. Cubesats)**

Recommendation #2:
- **Develop access to space beyond low earth orbit to allow for more realistic interplanetary radiation environments**

Recommendation #3:
- Develop facilities that mimic temperatures found in the interplanetary environment and on other planetary bodies for ground- and space-based research

Recommendation #4:
- **Accelerate development and access to new astrobiology facilities from proposal to flight**

Recommendation #5:
- Improve access to ground based facilities as well as the support to use them

Recommendation #6:
- Implement mechanisms to allow interaction with other ELIPS domains such as physiology / microbiology, to learn from common experiences, develop common instrumentation and prevent duplication
Topical Team which represents and engages the International Astrobiology and Astrochemistry community working since 2011 to formulate a roadmap and recommendations for future experiments/capabilities beyond those currently available.

Report with final recommendations for future flight studies submitted to ESA in 3Q/2013, related Journal Article also in preparation;

- ISS orbit is below main radiation belts – higher fluxes, more representative of the deep space environment are needed. Therefore, **access to polar, GTO, MEO or HEO orbits are required**
- ISS / LEO environment is polluted (gas plumes from ISS/visiting vehicles, outgassing from vehicle), and also atomic oxygen in LEO. **Higher orbits / other platforms would permit direct exposure of samples to solar irradiation and IGCR**
Conclusions (1)

• ESA has made its first steps in the CubeSat domain beyond education
• A small fleet of CubeSats are now under development by European research institutes and CubeSat industrial companies for launch in 2014-2016
• Missions are focussed on In-orbit Demonstration of miniaturised payloads and flight qualification of CubeSat platforms for scientific research and applications in low earth orbit
• Mission applications of nano-satellites (including CubeSats) operating in constellations or swarms have been identified and related studies have been initiated
• Studies for innovative and challenging future IOD CubeSat missions are underway
• Instrumentation to be flown and demonstrated can be used for exploration missions in the future
Conclusions (2)

- Currently no funded CubeSat mission for Astrobiology/Astrochemistry, BUT interest is increasing to look at alternatives for the ISS environment (ESF recommendations): Budget restrictions, reduction of time to implementation, use of further integration and miniaturisation, deep space environment
- CubeSat for interplanetary missions: Under internal consideration
- Funding available in the work plan for an instrumentation study and breadboarding: InSpectA, Infrared Spectrometer for in situ interrogation of Astrochemistry
- Miniaturised life support system for cell cultures under internal study
- Open to ideas from the community, suggestions welcome
Acknowledgment

Dr. Jason Hatton and Dr. Hervé Cottin for constructive discussions
THANK YOU

Robert Lindner
ESA/ESTEC
Keplerlaan 1
2201 AZ Noordwijk
The Netherlands
Tel: +31 71 565 3992
E-mail: Robert.Lindner@esa.int