Environmental Quality Control in space systems: the experience of the International Space Station

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Summary

- The Human Space Frontier, yesterday, today
- Space Station Environment Diagnostics
- Astronauts Environment Diagnostics
- Future Frontiers and Needs
Yesterday: a frontier at 400k km
Even a car!
Control and display system console

- Battery voltage and charge (Ah)
- Motor temperature
- Caution & Warning
- Crew action
Today: a beautiful frontier at 400 km
There is Italy... behind ISS

Image credit: NASA
European / Italian contribution

Permanent Modules

Logistics Modules

Columbus

Node 2

Node 3

Cygnus
PCM

PMM

MPLM

ATV - ICC

Cupola

50% habitable volumes from Torino - Italy

Image credit: NASA
A harsh environment

- Cosmic Rays
- Solar Particles
- Meteoroids & Debris
- Residual Atmosphere
- Plasma
- Vacuum
Astronauts in Space Environment

CUPOLA
Space Environment Diagnostics

COLUMBUS
Radiation Diagnostics

- What we monitor...
- Why?
- Where
- Radiation monitors
- Data analysis

A. Akulin
The Space Radiation Environment

Radiation Quantities
- Fluxes, Radiation Quality, Physical Dose, Biological dose
Why?

Radiation Protection of:
- Humans
- Electronics
- Materials

Scientific Research
Where?

Columbus
Columbus Radiation monitors

Dosemeter Equipment of DOSIS

Passive

Passive Detector Boxes

TLD Reader PILLE

Active

Detector Telescope DOSTEL

Alteino

Neutrondosemeter

Courtesy J. K. Pálfalvi, WRMISS 2010
Dosimeters location inside the Columbus European Laboratory (DOSIS)

10 NTDP packages / PILLE detectors inside Columbus
→ Exchange of NTDP packages every 6 months
→ Read out of PILLE detectors every 10 days

Courtesy J. K. Pálfalvi, WRMISS 2010
Position 1

Position 3D

Position 10

Courtesy J. K. Pálfalvi, WRMISS 2010
Radiation monitors

TISSUE EQUIVALENT PROPORTIONAL CHAMBER (US LAB)

Courtesy J. K. Pálfalvi, WRMISS 2010
EUROPEAN CREW PERSONAL DOSIMETER

ESA
IBMP
NASA
Personal
Dosemeters

Label
Nomex
CR39
Polyethylene Grid
TLD
CR39
PADC Housing
Nomex

Thales Alenia Space
ALTEINO: Cosmic Rays

ALTEINO → stack of silicon detectors (8x8 cm)

Courtesy Marco Casolino
ALTEINO + ESCHILO = Shielding

ESCHILO

Alteino

Pirs module

Apr. 2005 (ENEIFE mission)

Courtesy Marco Casolino
Thermoluminescence detectors (TLDs) and Nuclear Track Etch detectors, Scintillator/Silicon detectors, silicon telescope, tissue equivalent proportional counter (TEPC)

Courtesy G. Reitz
Results – radiation rate in time

ALTEINO

Courtesy M. Casolino
Results – world map

ALTEINO

Courtesy M. Casolino
Results – solar particle events

December 2006 Solar Particle Event

Courtesy M. Casolino
Comparison with/without shielding (ALTEINO)
Original Paper

Diagnostics of Space Plasma on Board International Space Station - ISS

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• **Plasma-wave processes** in near space zone (NSZ): interaction of ISS with ionosphere
• Improvement of **Combined Wave Diagnostics** (CWD) method of plasma flows fluctuation;
• Identification of **plasma flows disturbance sources** and EM fields in NSZ;
• **Geophysical research** of plasma-wave processes connected to solar interactions;
• Ecological monitoring of low-frequency EM radiation of anthropogenic character;
• **Plasma / EM fields disturbance** from ISS injection of electron and plasma beams;
• **Space weather** research in equatorial, middle-latitude and sub-aurora ionosphere.
The Astronauts Environment
What? Health of:
- Humans on board
- Their Environment
- Systems, devices, sensors
ISS / Columbus to Ground

Monitoring telemetry path

Space

Ground
Automatic
- Alarm triggering
- Fault Detection, Isolation and Recovery (FDIR)

With human intervention
Ground - Anomaly study:
- Crew activity onboard
- Trend analysis
- Secondary parameters calculations
- Cross-check among sensors

Anomaly resolution:
From ground
Astronauts
Columbus environmental monitoring

“Columbus Air Condition”

- O2 partial pressure
- CO2 partial pressure
- Cabin Temperature
- Relative humidity
- Total pressure
- Smoke detection
- To the ISS MCA (Major Constituent Analyzer)
Columbus environmental monitoring

Return Grid Sensor Housing
Centralized vs local monitoring

- CH4
- CO2
- O2
- H2O
- N2
- H2
Environmental Sensors
(Telemetry from ISS to COL-CC)

- Humidity [%]
- Carbon dioxide [mmHg]
- Total pressure [mmHg]
- Oxygen [mmHg]
- Cabin temperature [°C]

Trend Analysis
Some evident effects

Total pressure [mmHg]

Oxygen [mmHg]
Some evident effects

CO2 Partial Pressure during crew rotations

3 astronauts

6 astronauts

3 astronauts

PPCS1_Press_MVD min: 1.205 max: 2.802 unit: mmHg
PPCS2_Press_MVD min: 1.366 max: 2.970 unit: mmHg
Some evident effects

Relative Humidity

Astronauts activity in Columbus with stop of air exchange with ISS

CO2 Partial Pressure
CONTAMINATION ISSUE

• PT >40% → astronauts clean sensor
• Airborne contamination can trigger it

Countermeasure: new filter added
Columbus monitoring & control

Temperature Control & Dehumidification

Cabin Temperature [°C]

TCV opening on the active core [%]

Temperature control law
Devices and sensors health monitoring

- Health status (Built In Test)
- Active Status
- Electronic Unit temperature
- Input Current
- Motor temperature
Portable Work Station display

Implemented also on ground, at the flight control center.
Approach: to concentrate the FDIR activities on the lowest affected levels

SCOPE
➤ contain faults at equipment level

➤ avoid failures propagating to the higher level subsystem functions, impacting on its performance
Failure DETECTION

Isolation & Recovery

Identification

- Monitored parameter out of limits
- Monitored parameter exceeding its delta limit wrt a redundant one
- Monitored parameter out of its safe range
- Monitored discrete item not in one of its expected states

- Identification of valid symptom set from monitoring data
- Mapping of symptom set to potential failure
- Mapping of identified failure(s) onto one or more equipment
Detection → Caution & Warning

Columbus control Center CONSOLE

Displays pre-alarm signalling on ground

LOW ONBOARD

- Hard Level LOW GROUND
- Soft Level LOW GROUND
- Soft Level HIGH GROUND
- Hard Level HIGH GROUND

HIGH ONBOARD

Caution/ Warning Signals (PWS+Acoustic)

FDIR
Failure Detection ISOLATION & Recovery

Containement

Identify faulty equipment down to equipment level, compatible with recovery capabilities

To avoid propagation

✓ Capability to switch-off automatically

✓ Capability to switch-off via DMS instructions
Failure Detection Isolation & RECOVERY

Allow nominal operations to occur continuously and safely

Achieved by selecting redundant functional paths or alternative operating mode (functional redundancy).

Automated procedures implemented for different failures via FDIR FLAPS

FLight
APplication
SOftware
Medical Diagnostics

Radisens Diagnostics win €1m International Space Station contract

By Laura McGuigan

Cork firm Radisens Diagnostics has been awarded a €1 million contract by the European Space Agency, to develop an innovative blood testing device for use by astronauts on board the International Space Station and on various human spaceflight missions.

“Radisens Diagnostics’ success is the most recent example of an Irish company reaping significant benefits from Ireland’s membership of the European Space Agency (ESA) through Enterprise Ireland,” said Sean Sherlock T.D. Minister for Research and Innovation.

Finger-prick of blood to test patients for diabetes, heart disease, liver and kidney damage and thyroid conditions, with instant results.

Credits: insideireland.ie
MARS

Radiation issue

Mars travel dose
~ 0.8 Sv/y vs 0.5 Sv/y limit for ISS astronauts

Every year 1/3 of astronauts DNA would be damaged by Cosmic Rays
Earth From Mars - From Rover Spirit, one hour before sunrise, 63rd Martian day of its mission. Credit NASA
Challenges for diagnostics

Comm Time delay $\rightarrow$ Autonomy
Lessons will be learned!

Curiosity Rover Trailer - 08/10/2011

This animation shows the major mission events of the Curiosity rover's landing on Mars.
Thanks for your attention!

Questions?
Contact mail

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Credits

Unless otherwise indicated all picture credits are NASA