Status and operations of the external exposure facilities EXPOSE-E and EXPOSE-R on ISS

Elke Rabbow, Corinna Panitz, Andrea L´Afflitto, Günther Reitz

Deutsches Zentrum
DLR für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

EXPOSE - History

- 1997 AO for „Externally mounted payloads for 1st utilization phase” in 2002 by ESA
- EXPOSE (experiment) originally planned for SEBA Space Exposure Biology Assembly
- Proposal „ROSE“ for EXPOSE with 9 biological experiments + 2 chemical experiments
- Acceptance of ROSE with 6 biological experiments + 2 chemical experiments
- Withdrawal of Brasilian participation, change of position from SEBA to EuTEF for EXPOSE

- Due to Space Shuttle accidents and Columbus delay, now on
- EXPOSE-R on Russian ZVEZDA module (engineering model), originally scheduled for launch in 2006

ROSE Experiments on EXPOSE (1st Batch)

Experiment	original	PI	current	PI
ROSE 1	SUVEMCA	D.D. Wynn-Williams	ENDO	C. Cockell
ROSE 2	OSMO	R.L. Mancinelli	OSMO	R.L. Mancinelli
ROSE 3	SPORES	G. Horneck	SPORES	G. Horneck
ROSE 4	PHOTO	J. Cadet	PHOTO	J. Cadet
ROSE 5	SUBTIL	N. Munakata	SUBTIL	N. Munakata
ROSE 6	LUX	S. Kozubeck	/	/
ROSE 7	Dosimeters	T. Ohnishi	/	/
ROSE 8	PUR	G. Ronto	PUR	G. Ronto
ROSE 9	SEEDS	L.V. Nevzgodina	/	/
			Russian	V. Sychev
OC	AMINO	A. Brack	AMINO (SEEDS)	H. Cottin D. Tepfer
OC	ORGANIC	P. Ehrenfreund	ORGANIC	P. Ehrenfreund

EXPOSE - History

- Acceptance of ROSE with 6 biological experiments + 2 chemical experiments
- Withdrawal of Brasilian participation, change of position from SEBA to EuTEF for EXPOSE
- Due to Space Shuttle accidents and Columbus delay, now on
- EXPOSE-R on Russian ZVEZDA module (engineering model), originally scheduled for launch in 2006

- Today: ROSE with 6 biological experiments + 2 chemical experiments + additional Russian participation, currently scheduled for launch with Progress in November 2008 due to delay of contract

In the meantime, Shuttles are back to flight

- 2004 AO for 2nd Batch of EXPOSE Experiments, for EuTEF platform on Columbus

Experiments on EXPOSE 2nd Batch (AO 2004)

	Candidate Experiments	PI
AO-2004-099	Plant SEEDS Panspermia Experiment	D. Tepfer
AO-2004-146	PROCESS Experiment	H. Cottin
AO-2004-148	PROTECT Experiment	G. Horneck
AO 2004-149	ADAPT Experiment	P. Rettberg
AO-2004-150	LIFE Experiment	S. Onofri

EXPOSE –R and -E Experiment requirements

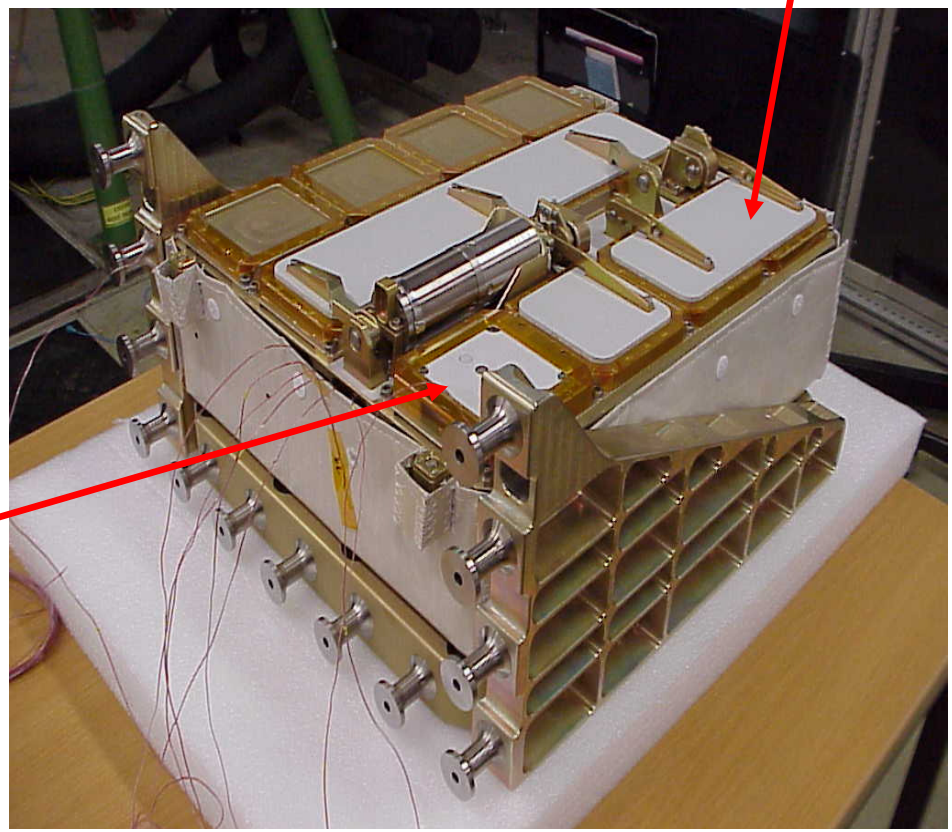
- Extraterrestrial solar and galactic radiation
- Vacuum (approximately 10^{-4} Pa near ISS)
- Simulated Mars atmosphere (-E) or Argon atmosphere (-R)
- UV-radiation (extraterrestrial radiation cannot be simulated accurately)
- Except for R3D, all experiments require
  - passive exposure to the selected space parameters and
  - return of the samples to Earth for analysis

Therefore the external platforms on ISS provide ideal exposure conditions for the investigations of the scientific groups in EXPOSE –R and -E

EXPOSE Facility

3 Trays
4 Compartments
each
Experiments
biological
chemical
radiometrical

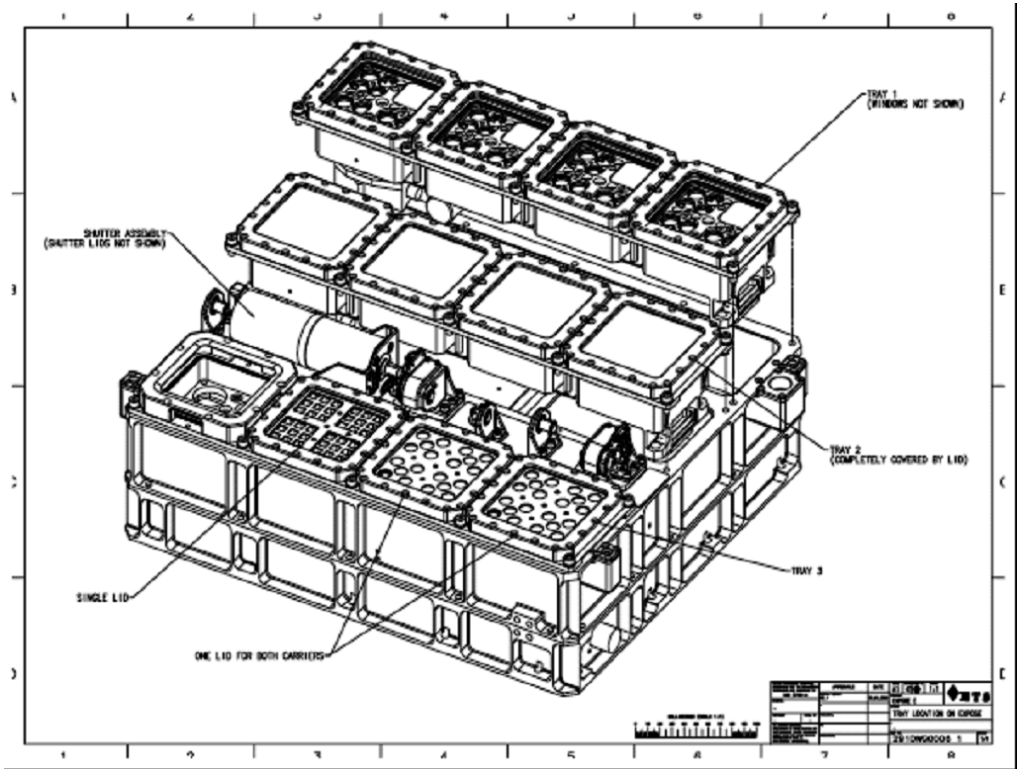
R3D
3-1

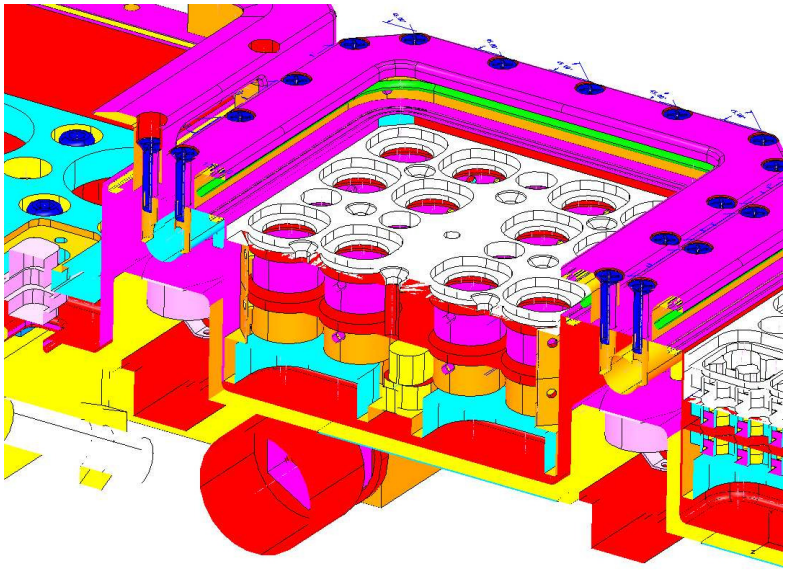


Courtesy: KT

EXPOSE Experiment HW

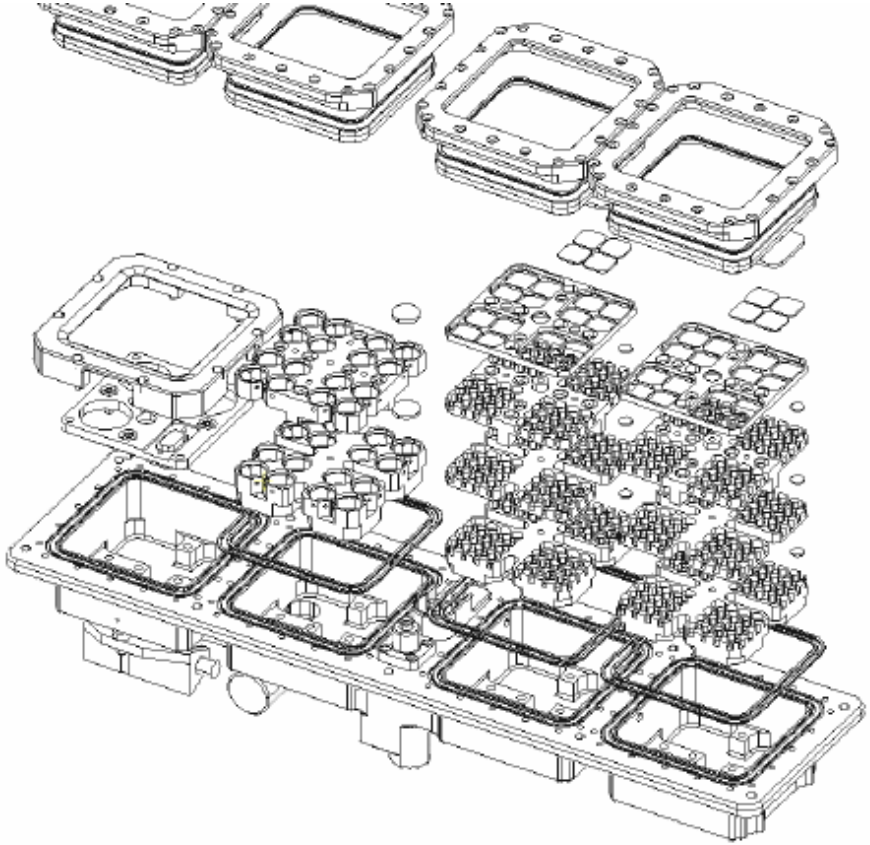
Tray- and Sample Carrier Design -E

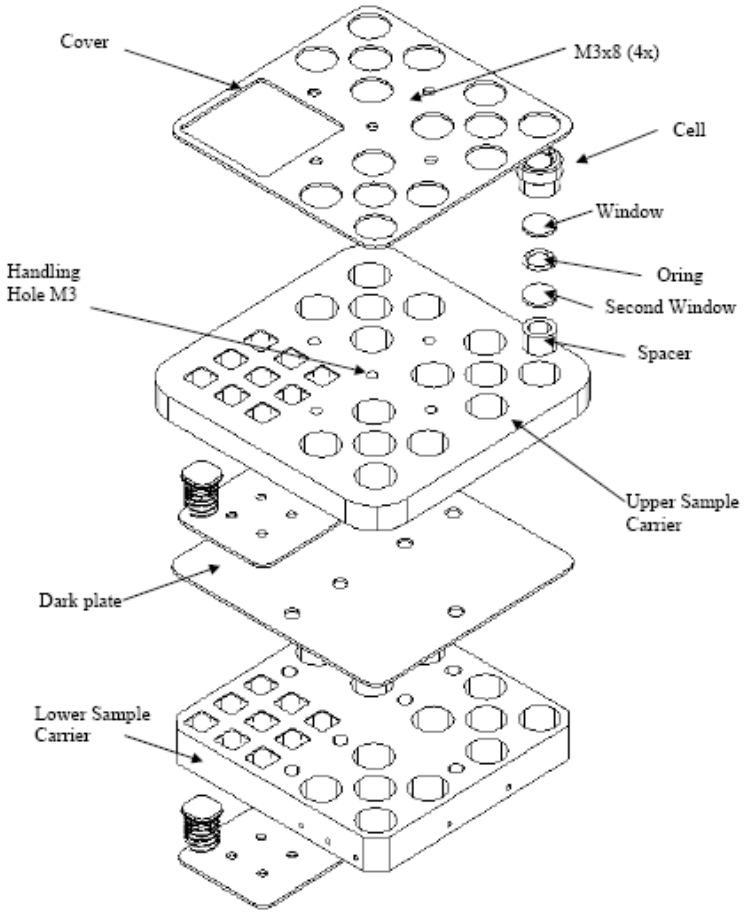




EXPOSE Experiment HW

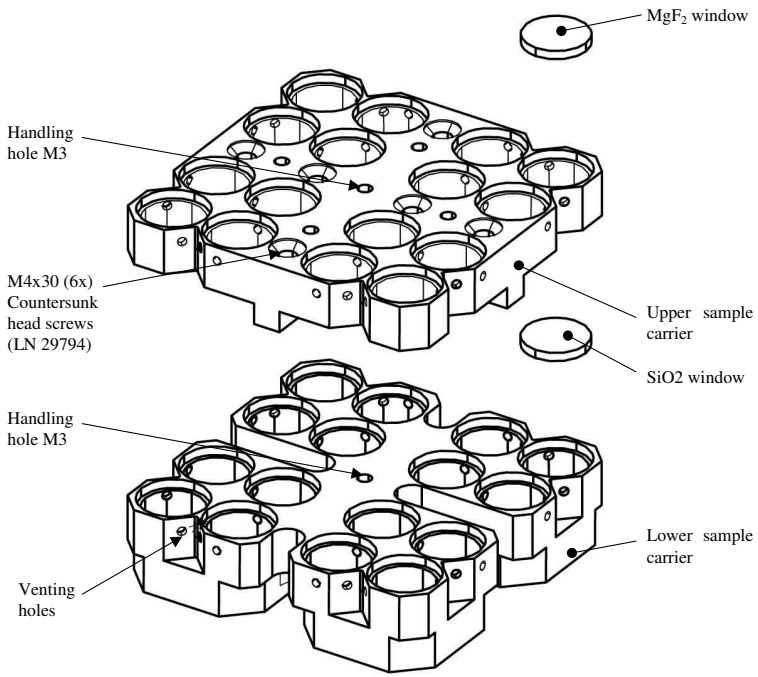
Sample Carrier Design Trays – R,

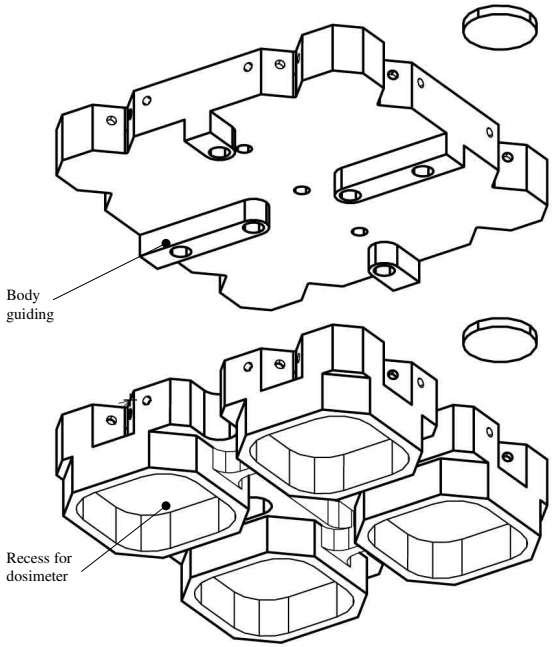




EXPOSE Experiment HW

Sample Carrier Design Trays – E, 1 and 2





EXPOSE – R Preflight Test Programm

- 5 EVTs performed at DLR plus
- 1 additional biocompatibility Test performed for Russian experiments
- EST performed at DLR for all ROSE experiment HW
- EST for chemical experiment, Russian experiment and SEEDs HW for -R (Tray 1)
  - pending –

- Additional exposure to simulated space parameters during EST for sample testing purposes provided

Will be presented by Corinna Panitz for SPORES

EXPOSE – R Preflight Test Programm

EVT-R1 18.07.02 - 30.07.02
Vacuum 7 x 10^{-5} Pa
Vacuum 10^{-5} Pa
Temperature 40°C, 1 atm air
UV irradiation, monochromatic 254 nm, 1 atm air Fluences: 10 Jm^{-2} 100 Jm^{-2} 1000 Jm^{-2}
ROSE 1,3,5,8

EVT-R2 12.02.03 - 26.03.03
Temperature limit 60°C Argon 1 atm Vacuum 1,7 x 10^{-5} Pa
Temperature limit -80°C Vacuum 1,7 x 10^{-5} Pa
Temperature oscillation 50 cycles, -20°C to + 20°C, Argon 1 atm Vacuum 1,7 x 10^{-5} Pa
ROSE 2,3,5,8

EVT-R 3 23.10.03 - 12.11.03 12.02.04 - 03.03.04
Vacuum 8 x 10^{-5} Pa Argon 1 atm + UV irradiation, polychromatic 200-400 nm Fluences: (ND Filter) 3,33 x 10^{3} kJm^{-2} 33 kJm^{-2} 333 Jm^{-2} 3 Jm^{-2} Temperature 20°C, 0°C during irradiation
ROSE 1,2,3,5,8

EVT-R 4 30.05.05 - 23.06.05 29.11.05 - 19.12.05
Vacuum 1,1 x 10^{-4} Pa Argon 1 atm + UV irradiation, Deuterium lamp > 160 nm Fluences: (ND Filter) 2,6 x 10^{2} kJm^{-2} 26 kJm^{-2} 260 Jm^{-2} 2,6 Jm^{-2} Temperature 20°C, 10°C during irradiation
ROSE 3,5,8

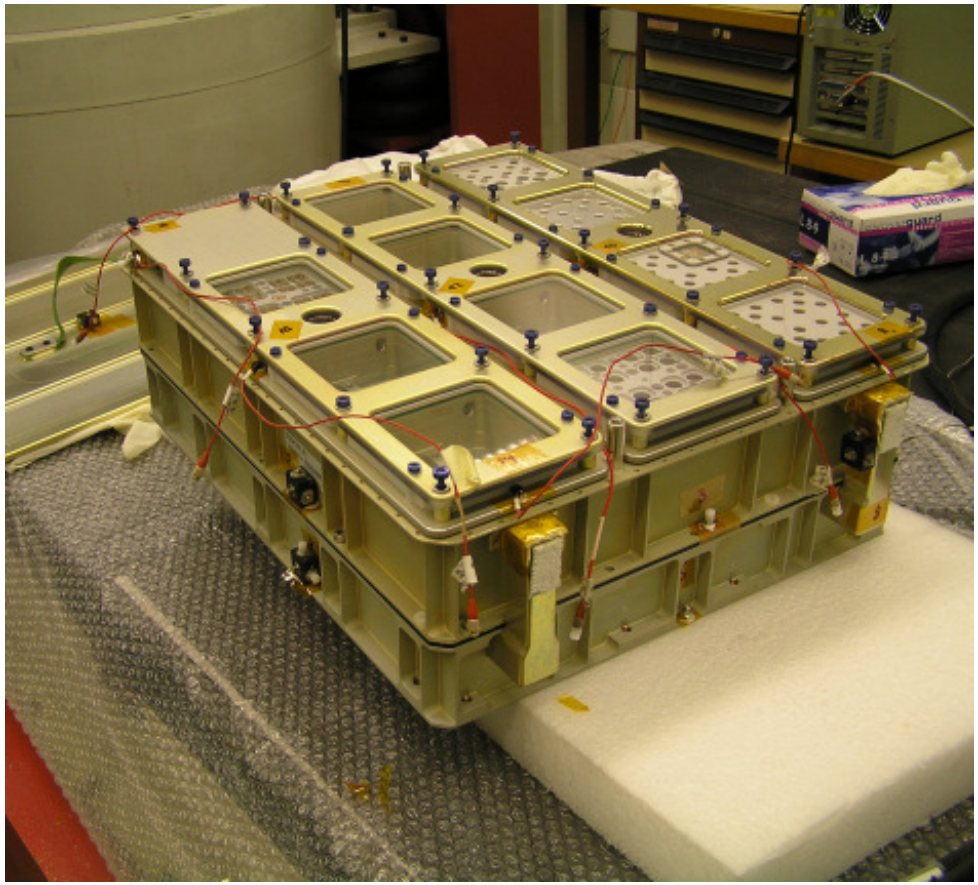
EVT-R 5 14.07.06 - 23.08.06
Vacuum 1,1 x 10^{-4} Pa Argon 1 atm + UV irradiation, polychromatic 200-400 nm Fluences: (ND Filter) 9,1 x 10^{4} kJm^{-2} 9,1 x 10^{2} kJm^{-2} 9,1 kJm^{-2} 91 Jm^{-2} + UV irradiation, Deuterium lamp > 160 nm Fluences: (ND Filter) 83 kJm^{-2} 830 Jm^{-2} 8,3 Jm^{-2} 0,08 Jm^{-2} Temperature 20°C, 10°C during irradiation
ROSE 1,2,3,4,5,8

Control experiment,
1 atm air, dark, room temperature

EXPOSE – R Preflight Test Programm - EST

EXPOSE – R Mission Sample Integration

- Currently, HW ready and tested
- Integration of Flight and Mission Ground Reference Sample at DLR ongoing
  - Samples from PIs requested and partly received
  - Available HW ready for integration



Curtesy: KT

Final number of samples for Flight:

Biological: 1062

Chemical: 130

Dosimetrical: 27

Total Flight + Ground: 1219 x 2 = 2438

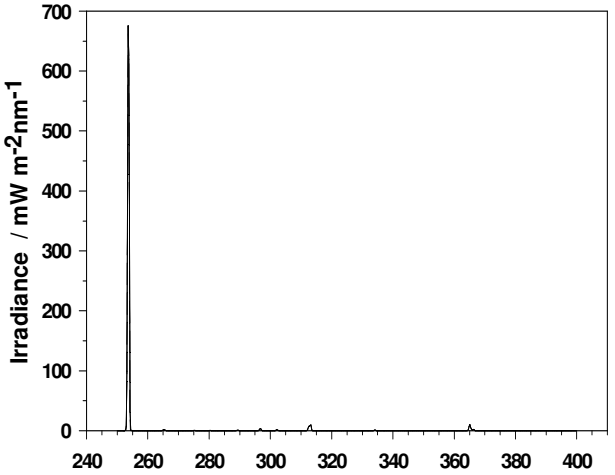
Experiments on EXPOSE 2nd Batch (AO 2004)

	Accepted Experiments	PI
AO-2004-099	Plant SEEDS Panspermia Experiment	D. Tepfer
AO-2004-146	PROCESS Experiment	H. Cottin
AO-2004-148	PROTECT Experiment	G. Horneck
AO 2004-149	ADAPT Experiment	P. Rettberg
AO-2004-150	LIFE Experiment	S. Onofri
	DOSIS / DOBIES	G. Reitz / F. Vanhavere
	R3D-E	D.-P. Häder

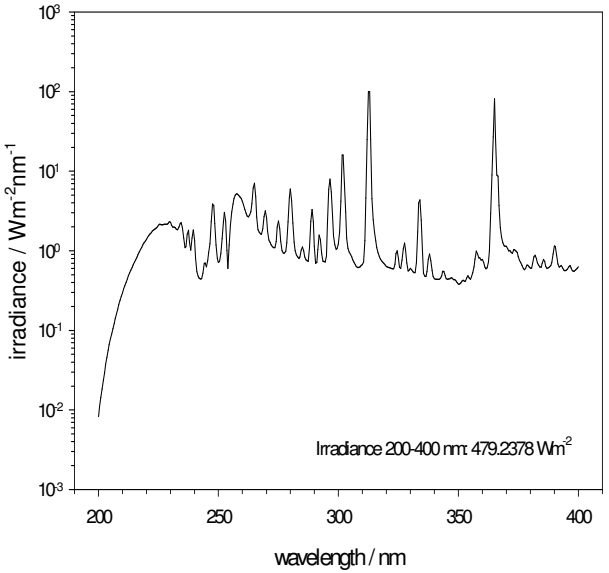
EXPOSE – E Preflight Test Programm

EVT 1: PSI 6

EVT 1: Hg-Low pressure Lamp



EVT 1: SOL2000



EXPOSE-E EVTs:

EVT 2: PSI 2

EVT-E 1 05.09.06 - 26.09.06
Vacuum 10^{-5} Pa
Vacuum 10^{-5} Pa
Temperature oscillation 50 cycles, -20°C to + 20°C, 1 atm air
UV irradiation, monochromatic 254 nm, 1 atm air Fluences: 10 Jm^{-2} 100 Jm^{-2} 1000 Jm^{-2}
UV irradiation, polychromatic 200-400 nm, 1 atm air Fluences: 1.5 kJm^{-2} 1.5 x10^{3} kJm^{-2} 1.5 x10^{5} kJm^{-2}

EVT- E 2 09.10.06 – 05.01.07
Vacuum 10^{-5} Pa + UV irradiation, polychromatic 200-400 nm, Fluence: 1.5 x 10^{5} kJm^{-2} 1.5 x 10^{2} kJm^{-2}
Simulated CO_2 Mars atmosphere 600 Pa + UV irradiation, polychromatic 200-400 nm, Fluence: 1.5 x 10^{5} kJm^{-2} 1.5 x 10^{2} kJm^{-2}

Control experiment, 1 atm air, dark, room temperature

EXPOSE-E EVTs:

EVT 1

Experiment	DC	Vacuum		Temp cycles	254 nm J/m²			200-400 nm kJ/m²		
		1h	1 week	50	10	100	1000	1,5	1,5x10⁴	1,5x10⁵
ADAPT										
168 wt	3x	3x	3x	3x	3x	3x	3x	3x	3x	3x
168 new	3x	3x	3x	3x	3x	3x	3x	3x	3x	3x
Anabaena 1 No	./.	1	4	7	10	13	16	19	22	25
2 No	./.	2	5	8	11	14	17	20	23	47
3 No	./.	3	6	9	12	15	18	21	24	27
Halo Helga	3x	3x	3x	/.	3x	3x	3x	3x	3x	3x
PROTECT										
168 wt	3x	3x	3x	3x	3x	3x	3x	3x	3x	3x
168 wt Alu	3x	3x	3x	3x	3x	3x	3x	3x	3x	3x
B atroph	3x	3x	3x	3x	3x	3x	3x	3x	3x	3x
B pumilus	3x	3x	3x	3x	3x	3x	3x	3x	3x	3x
LIFE										
123	./.	./.	6x	3x	3x	3x	3x	./.	./.	./.
134	./.	./.	3x	6x	3x	3x	3x	./.	./.	./.
CM 1 – 1 No	1.1	1.1	1.1	1.1	1.2	1.2	1.2	1.2	1.2	1.2
2 No	1.3	1.2	1.2	1.2	1.1	1.1	1.2	1.1	1.1	1.2
3 No	1.4	1.2	1.2	1.2	1.1	1.1	1.1	1.1	1.1	1.1
CA 1 – 1 No	1.1	1.1	1.1	1.1	1.4	1.4	1.4	1.4	1.4	1.4
2 No	1.1	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
3 No	1.2	1.4	1.4	1.4	1.1	1.1	1.1	1.1	1.1	1.1
CA 2 – 1 No	2.2	2.3	2.2	2.2	2.4	2.4	2.4	2.4	2.4	2.4
2 No	2.2	2.2	2.4	2.4	2.2	2.2	2.4	2.2	2.2	2.4
3 No	2.4	2.4	2.4	2.4	2.2	2.2	2.2	2.2	2.2	2.2
CR 1 – 1 No	./.	1.1	1.10	/.	1.6	1.5	1.4	1.7	1.8	1.9
2 No	./.	1.2	1.12	/.	./.	./.	./.	./.	./.	./.
3 No	./.	1.3	./.	/.	./.	./.	./.	./.	./.	./.
CR 2 – 1 No	2.11	./.	./.	2.2	2.6	2.5	2.4	2.7	2.8	2.9
2 No	2.12	./.	2.9	2.3	./.	./.	./.	./.	./.	./.
3 No	./.	./.	./.	2.10	./.	./.	./.	./.	./.	./.
CR 3 – 1 No	3.35	3.25	3.22	3.19	3.1	3.6	3.7	3.28	3.31	3.34
2 No	3.36	3.26	3.23	3.20	3.2	3.5	3.8	3.11	3.30	3.36
3 No	3.37	3.27	3.24	3.21	3.3	3.4	3.9	3.10	3.29	3.37
Apth X ele	Rest	1disc	1 disc	1 disc	1 disc	1disc	1 disc	1disc	1 disc	1 disc
Myco X ele	Rest	1disc	1 disc	1 disc	1 disc	1disc	1 disc	1disc	1 disc	1 disc
Apot R geo	Rest	1disc	1 disc	1 disc	1 disc	1disc	1 disc	1disc	1 disc	1 disc
SEEDS										
A. thaliana TT4	./.	./.	./.	/.	./.	./.	./.	./.	./.	S No.1
A. thal. Ler-0	./.	./.	./.	/.	./.	./.	./.	./.	./.	S No.2
A. thal. WS	./.	./.	./.	/.	./.	./.	./.	./.	./.	S No.3
N. tabacum	./.	./.	./.	/.	./.	./.	./.	./.	./.	S No.4
B. napus	./.	./.	./.	/.	./.	./.	./.	./.	./.	S No.5
Flavonoids	./.	./.	./.	/.	./.	./.	./.	./.	./.	S No.6

EVT 2

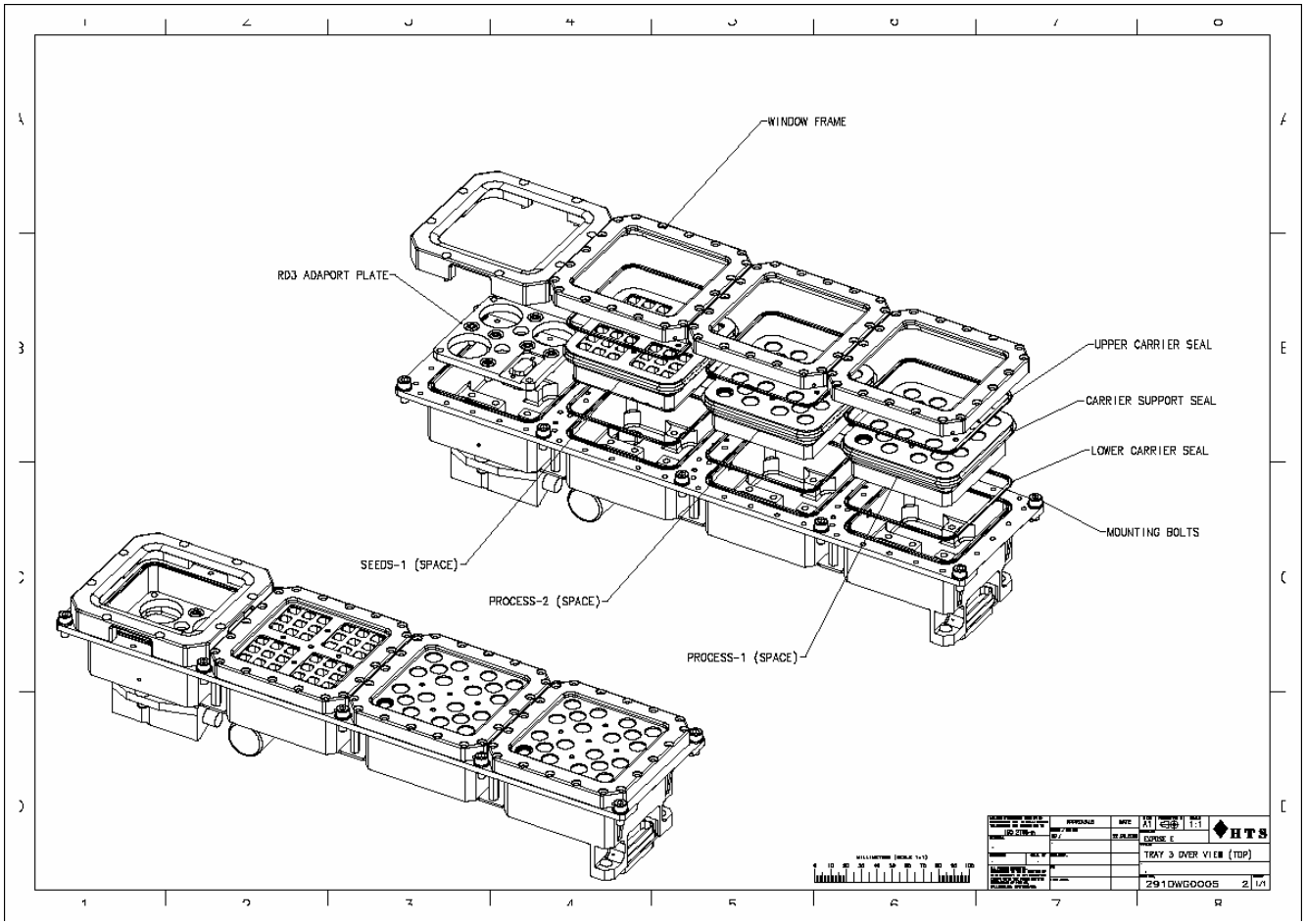
Experiment	Vacuum dark	Vacuum 200-400 nm J/m²	MARS CO_2 dark	MARS CO_2 200-400 nm kJ/m²
ADAPT				
168 wt 10^3	3x	3x	3x	3x stacks
168 wt 10^5	3x	3x	3x	3x stacks
168 new	3x	3x	./.	./.
Anabaena 1 No	34	37	28	31
2 No	35	38	29	32
3 No	36	39	30	33
Halo Helga	3x	3x	3x	3x
PROTECT				
168 wt 10^3	3x	3x	3x	3x stacks
168 wt 10^5	3x	3x	3x	3x stacks
168 wt Alu	3x	3x	3 on 1	3 on 1
B atroph	3x	3x	3x	3x
B pumilus	3x	3x	3x	3x
LIFE				
123	./.	./.	3x	3x
134	./.	./.	3x	3x
CM 1 – 1 No	1.1	1.1	1.1	1.1
2 No	1.1	1.1	1.1	1.1
3 No	1.1	1.1	1.1	1.1
4 No	1.2	1.2	./.	./.
CA 1 – 1 No	1.1	1.1	1.1	1.1
2 No	1.1	1.1	1.3	1.3
3 No	1.1	1.1	1.4	1.4
4 No	1.3	1.3	./.	./.
5 No	1.4	1.4	./.	./.
CA 2 – 1 No	2.4	2.4	2.4	2.4
2 No	2.4	2.4	2.4	2.4
3 No	2.4	2.4	2.4	2.4
CR 1 – 1 No	./.	./.	./.	./.
2 No	./.	./.	./.	./.
3 No	./.	./.	./.	./.
CR 2 – 1 No	./.	./.	./.	./.
2 No	./.	./.	./.	./.
3 No	./.	./.	./.	./.
CR 3 – 1 No	3.44	3.42	3.38	3.40
2 No	3.45	3.43	3.39	3.41
3 No	./.	3.46	./.	./.
LF 1 – 1 No	1.4	1.4	./.	./.
2 No	1.5	1.5	./.	./.
3 No	1.6	1.6	./.	./.
4 No	1.7	1.7	./.	./.
5 No	1.9	1.9	./.	./.
Apth X ele	1 disc	1 disc	1 disc	1 disc
Myco X ele	1 disc	1 disc	1 disc	1 disc
Apot R geo	1 disc	1 disc	1 disc	1 disc
SEEDS				
A. thaliana TT4	S No.33	S No.31	S No.15	S No.12
A. thaliana Ler	S No.34	S No.32	S No.17	S No.10

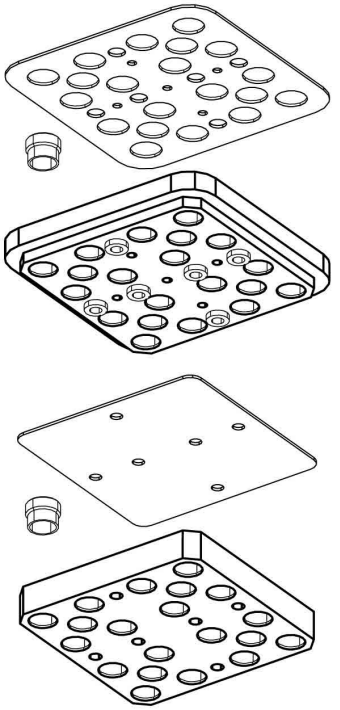
EXPOSE-E: EST

EST parameter					
Exposure Experiment planned:		**Exposure Experiment performed:**			
	Duration	**Start**	**End**	**Duration**	**Exposition**
Vacuum 10^{-5} Pa	1 week	23.04.07, 14:00	03.05.07 11:00	10 days	3 x 10^{-4} Pa
CO_2 atmosphere 600 Pa	1 week	20.04.07 14:00	03.05.07 11:00	13 days	610 Pa
Temperature < 60°C		23.04.07	27.04.07		max. 57°C
UV irradiation, polychromatic 200-400 nm, Fluences: As much as possible, max: 1,5x10^5 kJm^{-2}	86 h 56 m 37 s	23.04.07 14:00	27.04.07 9:00	86 h 56 m 00 s	479,2 Wm^{-2} 1,5x10^5 kJm^{-2}

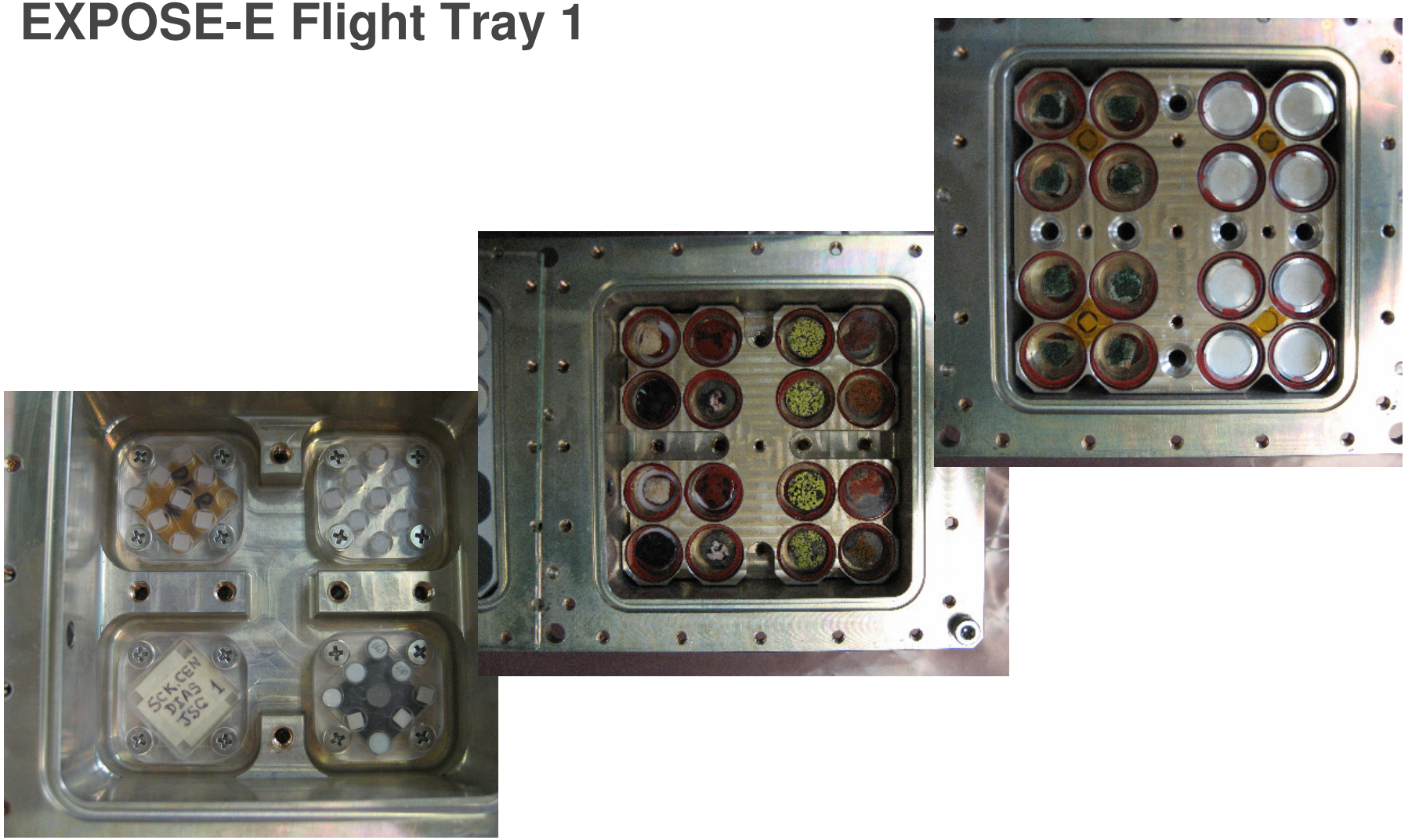
EXPOSE-E Mission Preparation

Flight / Ground Sample Accommodation – launch 6.12.07



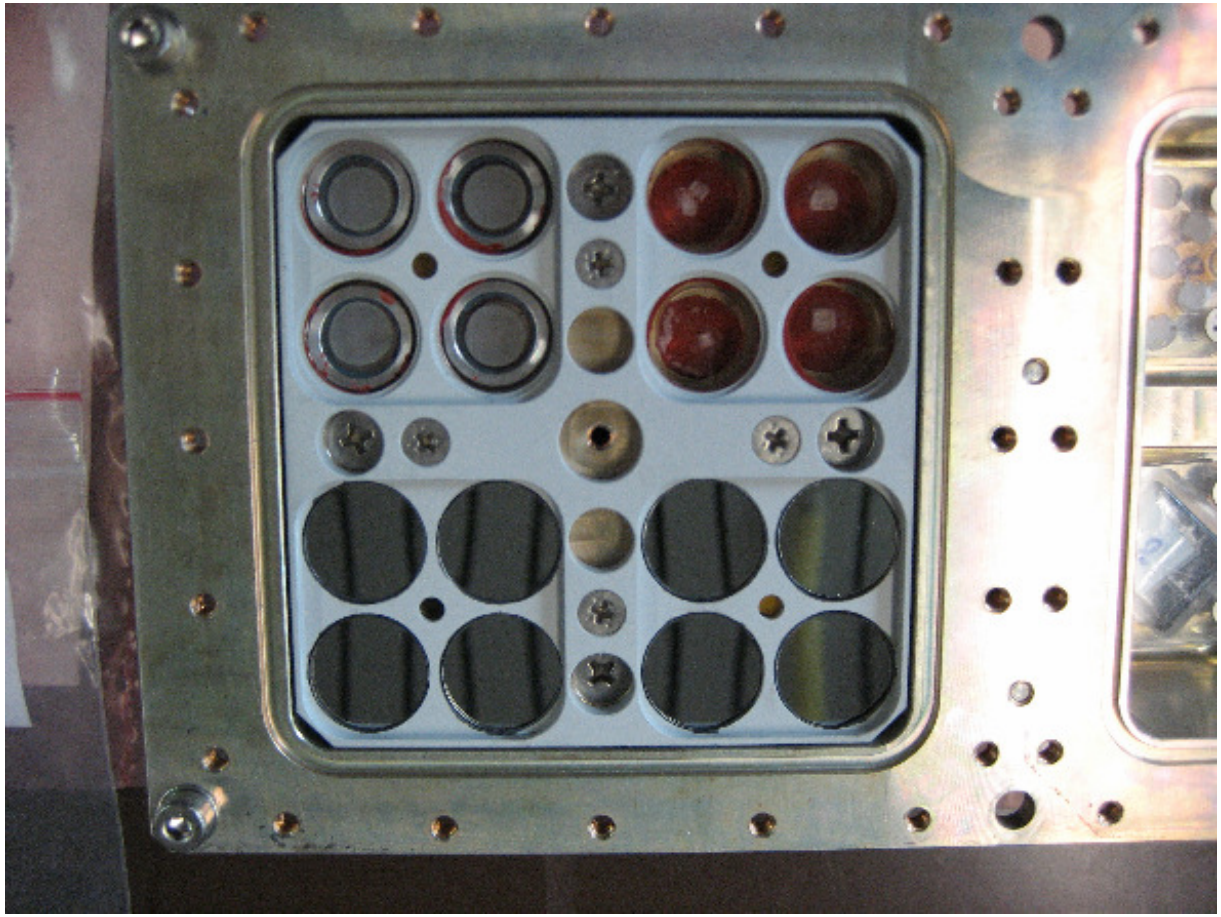


EXPOSE-E Flight Tray 1



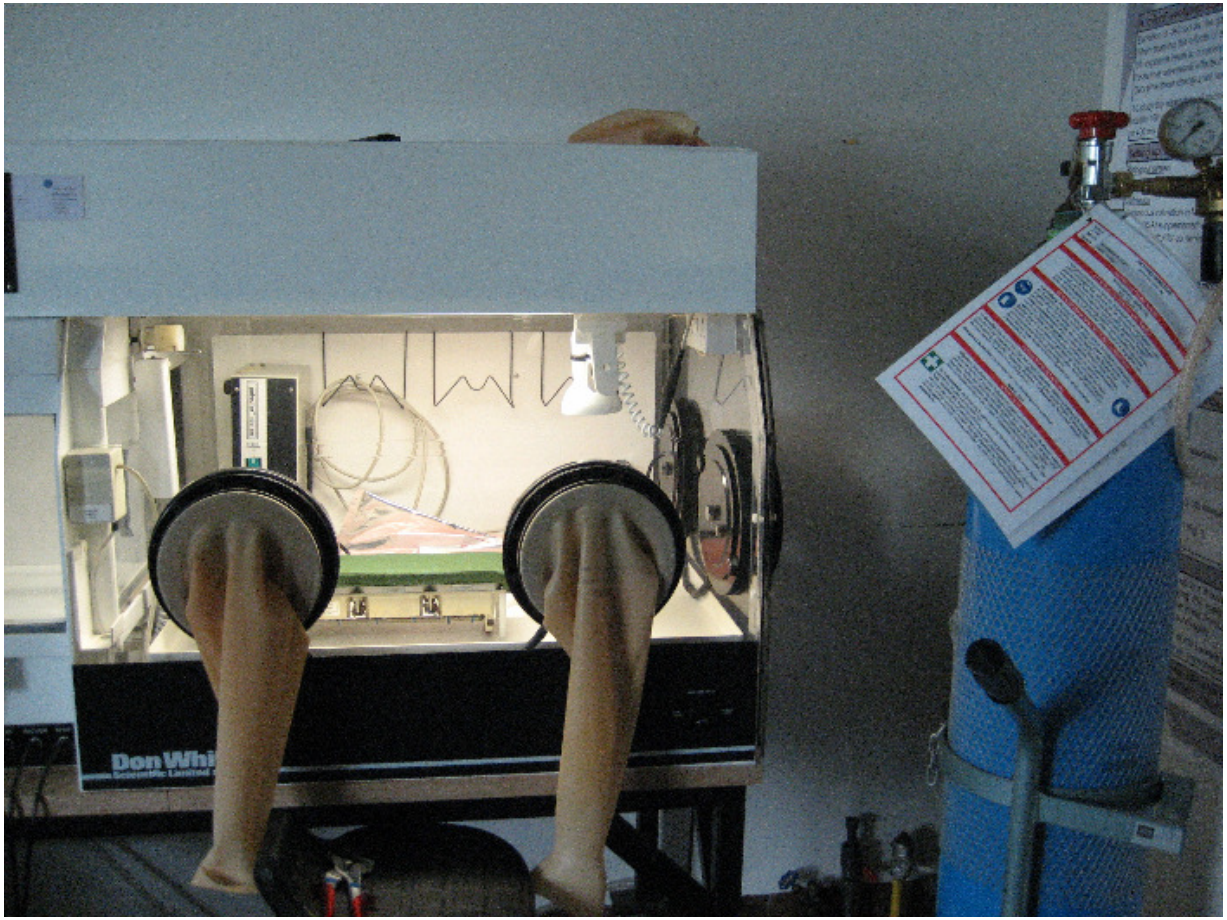
Integration carrier in Tray 1 – here Dosis, LIFE, ADAPT/ PROTECT

EXPOSE-E Flight Tray 1



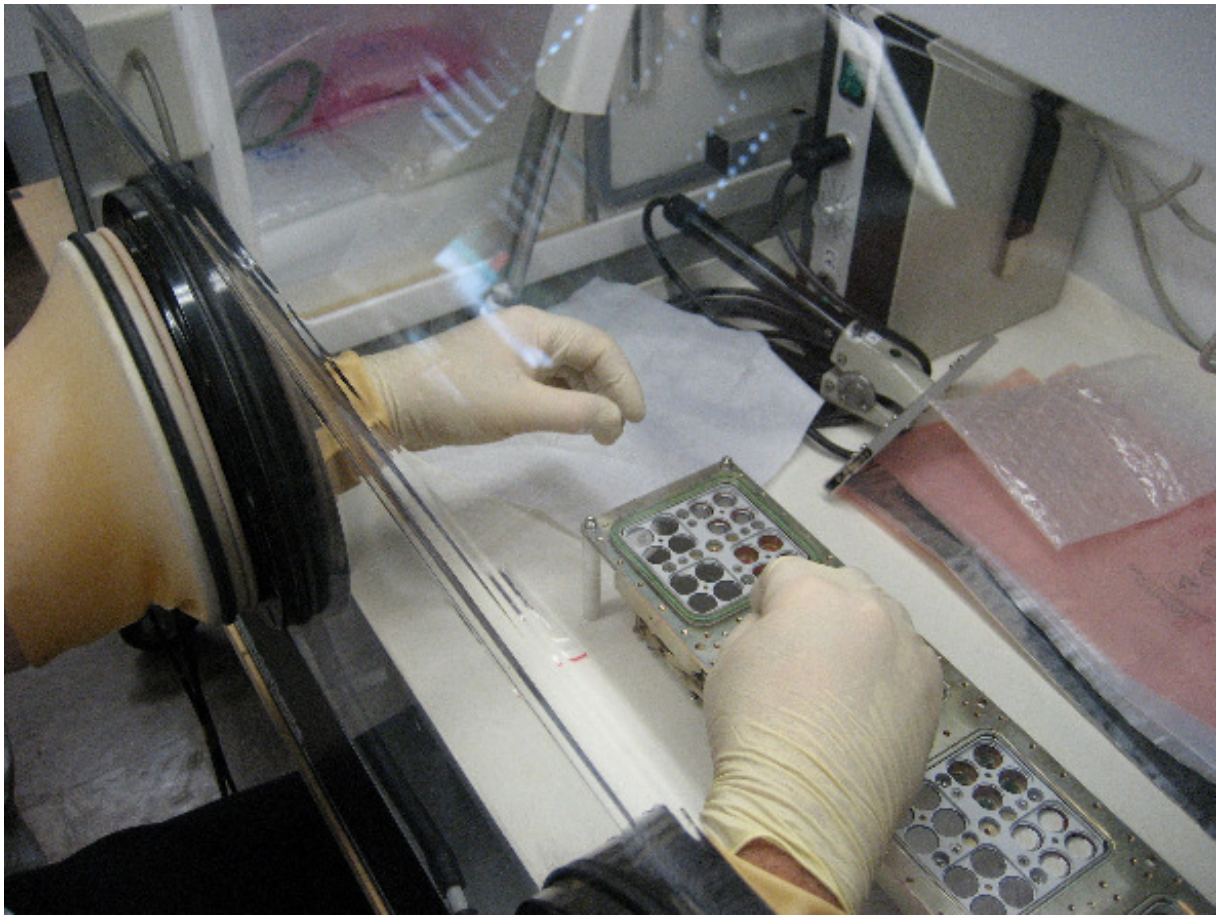
Filter frame mounted - here ADAPT

EXPOSE-E Flight Tray 2



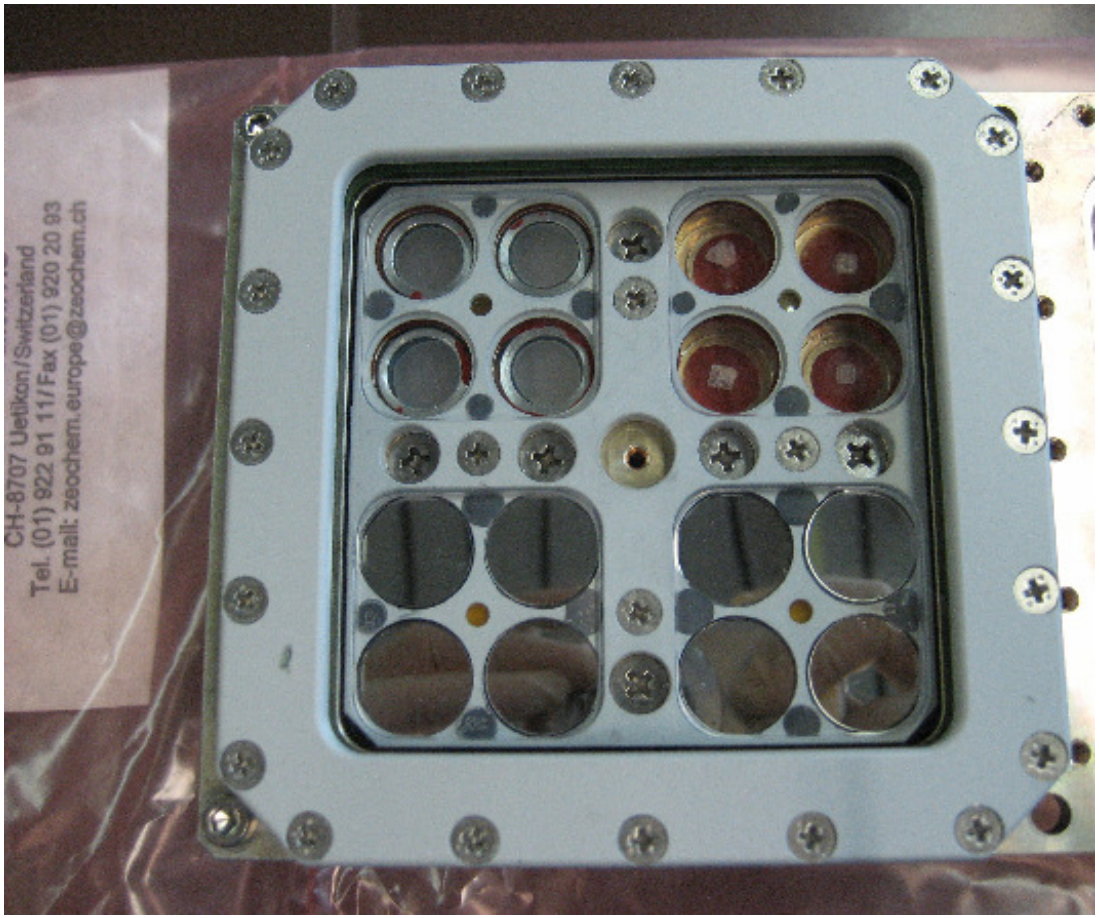
Tray with protection in N_2 / CO_2-workbench

EXPOSE-E Flight Tray 1



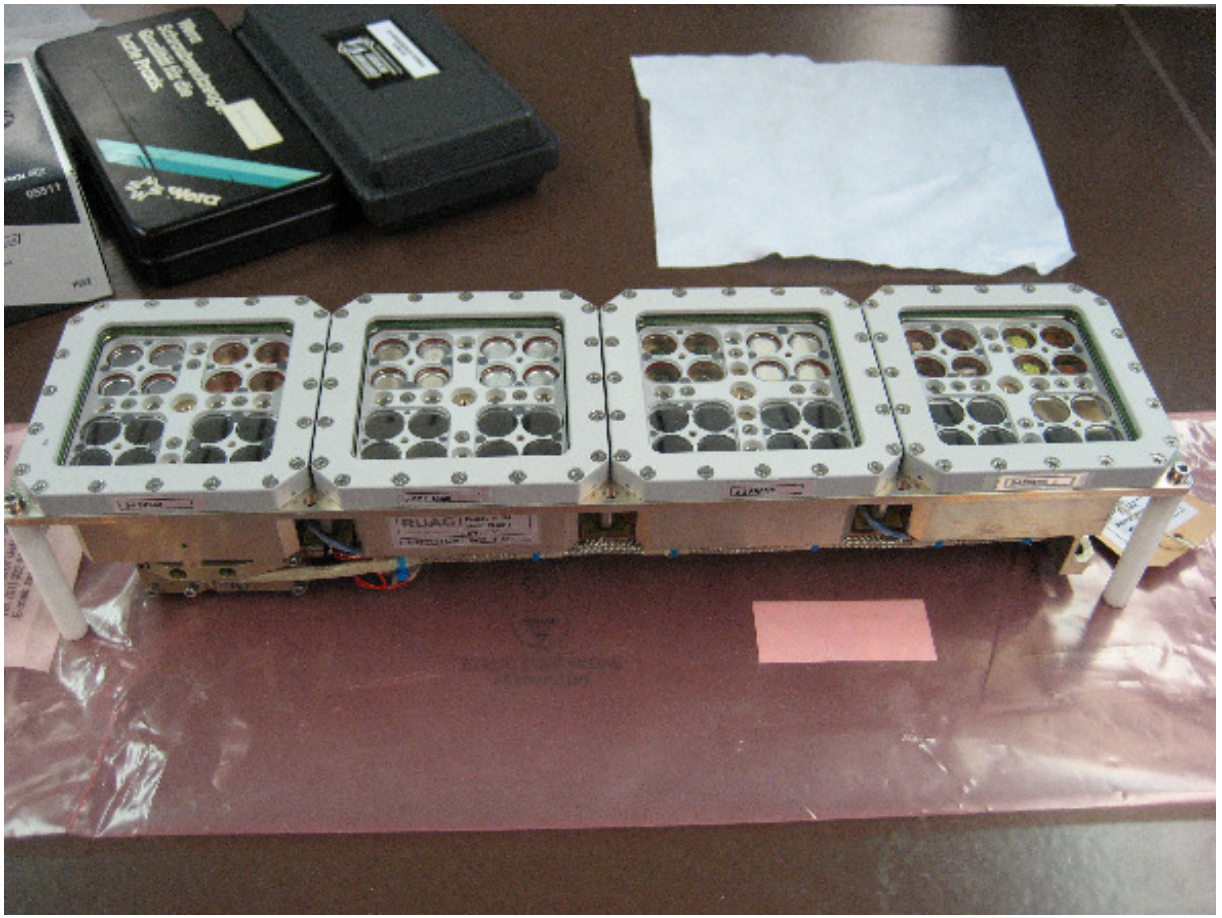
2 O-rings for the top window, 3rd in window frame…

EXPOSE-E Flight Tray 2



…Window and Window Frame – here ADAPT

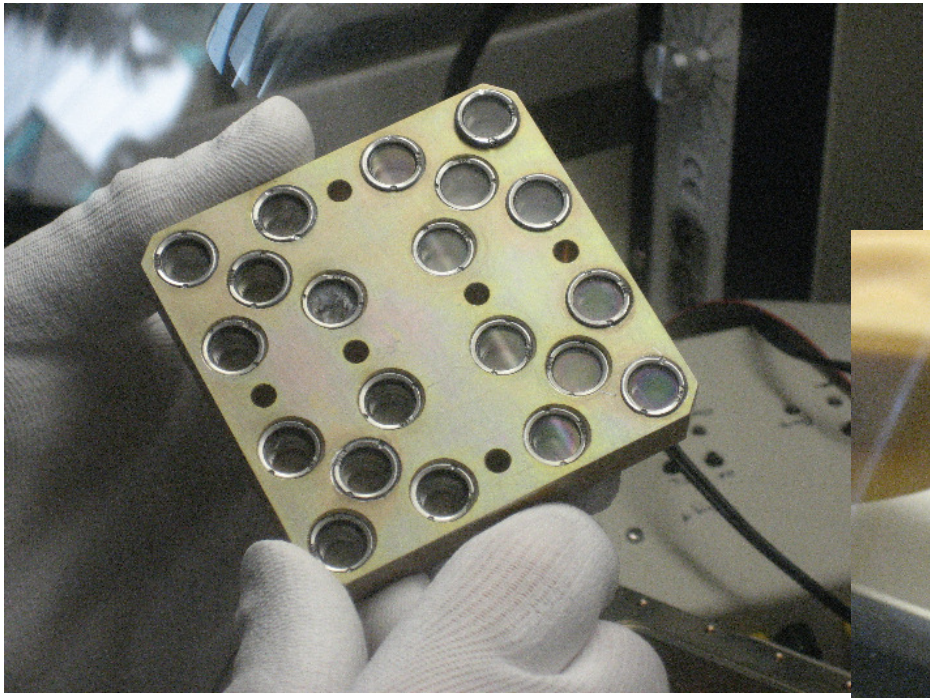
EXPOSE-E Flight Tray 2



Tray 2 closed (in air, exchanged to 10 mbar CO_2 to remain in Tray 2)

EXPOSE-E Flight Tray 3

EXPOSE FM: Sample Carrier Tray 3 PRCESS + SEEDS



EXPOSE-E Flight Tray 3

R3D, PROCESS and SEEDS carrier integrated in N_2

EXPOSE-E Trays Shipping

EXPOSE-E Facility Commanding and Data at MUSC

Flight Operations:

- Check Out and Comissioning
  - •Commanding of lids (-E only) and valves
- Data retrieval on the following parameters

Pressure:

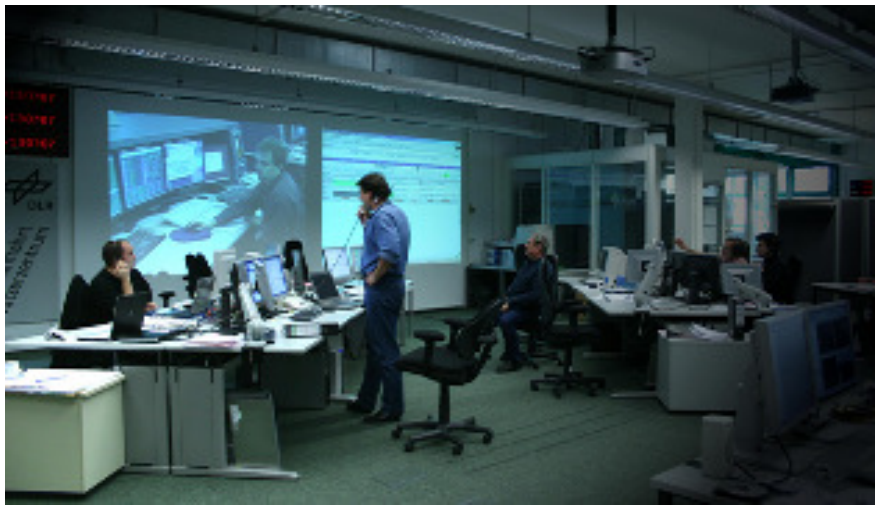
- •Status of the valves, decrease of pressure in EXPOSE trays

Solar extraterrestrial UV and ionizing radiation:

- •Status of lids (-E only)
- •Data of 4 UV sensors and one radiometer on trays near irradiated sample surface
- •Experimental data from R3D

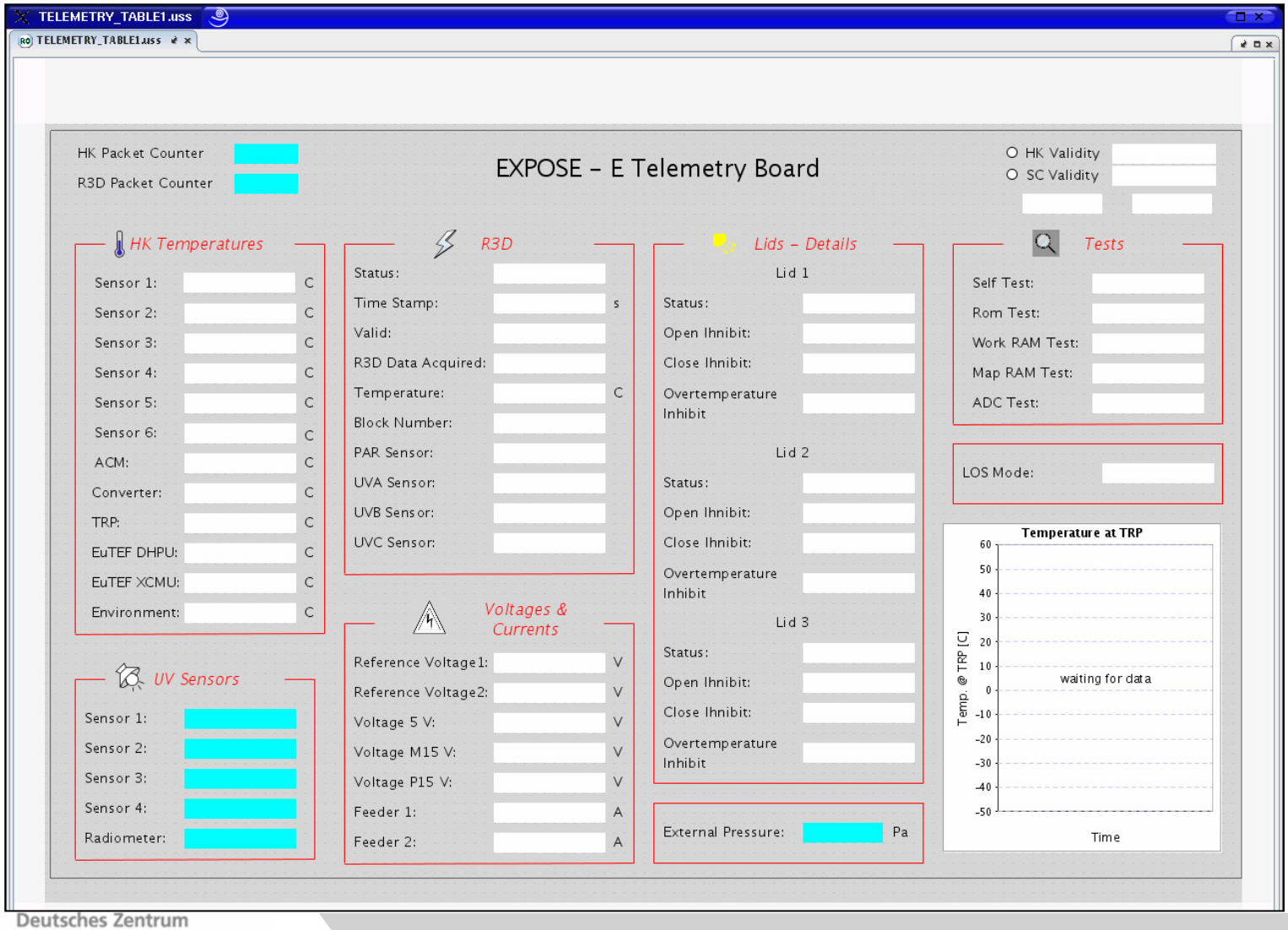
Temperature:

- •Data of 6 temperature sensors at attached near samples
- •2 Housekeeping temperatures

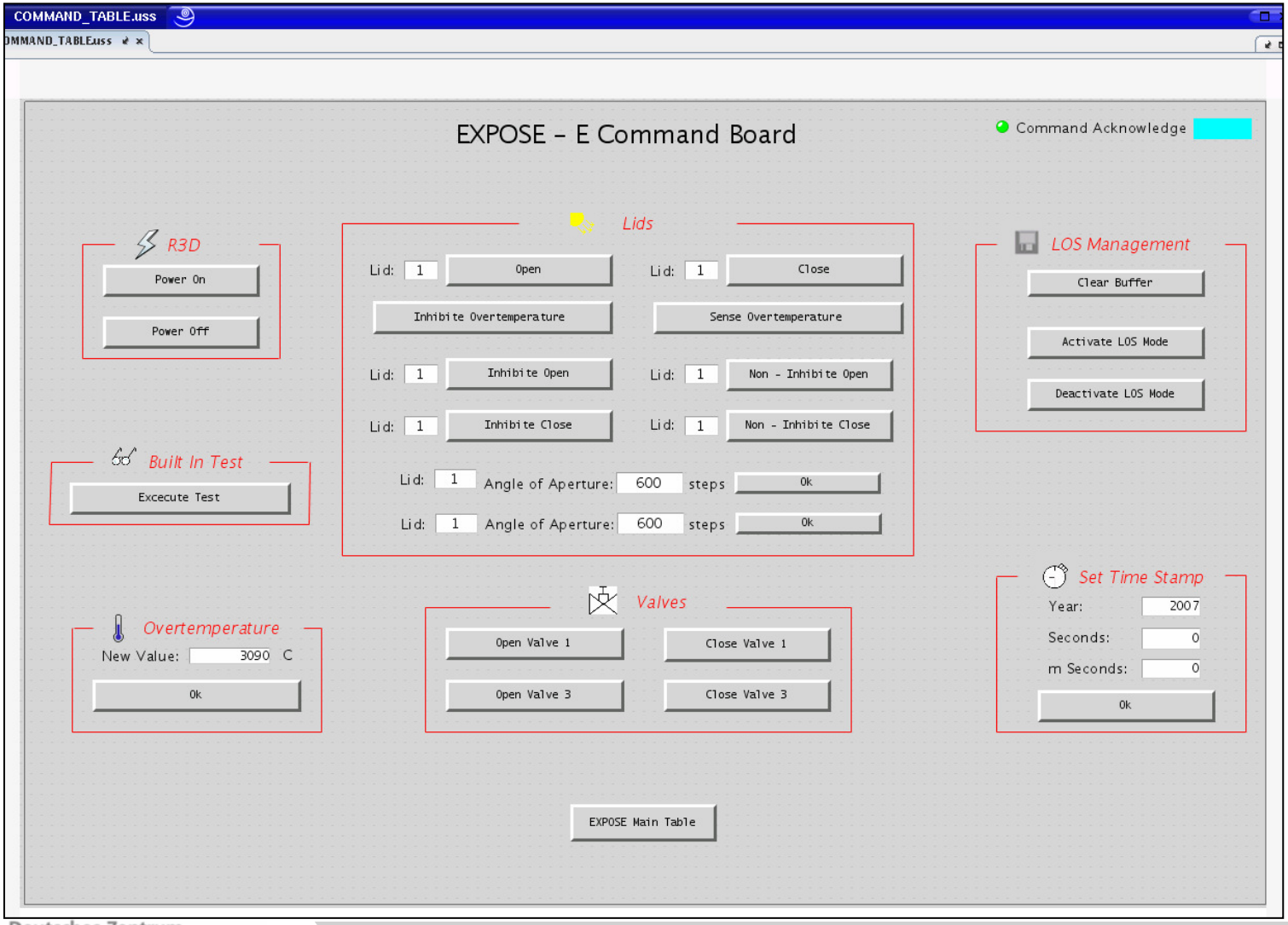


All data available by telemetry and available to PIs / Ground Reference on FTP-Server

EXPOSE-E Data



EXPOSE-E Commanding



EXPOSE-E Status Mission Start

Flight HW was transported to Cape Canaveral and Integrated on the European Technology Exposure platform EuTEF

EuTEF was integrated into the Shuttle bay

Atlantis STS 122 was transported to launch pad A39 for launch on December 6th 2007

Launch was delayed due to fuel sensor malfunction

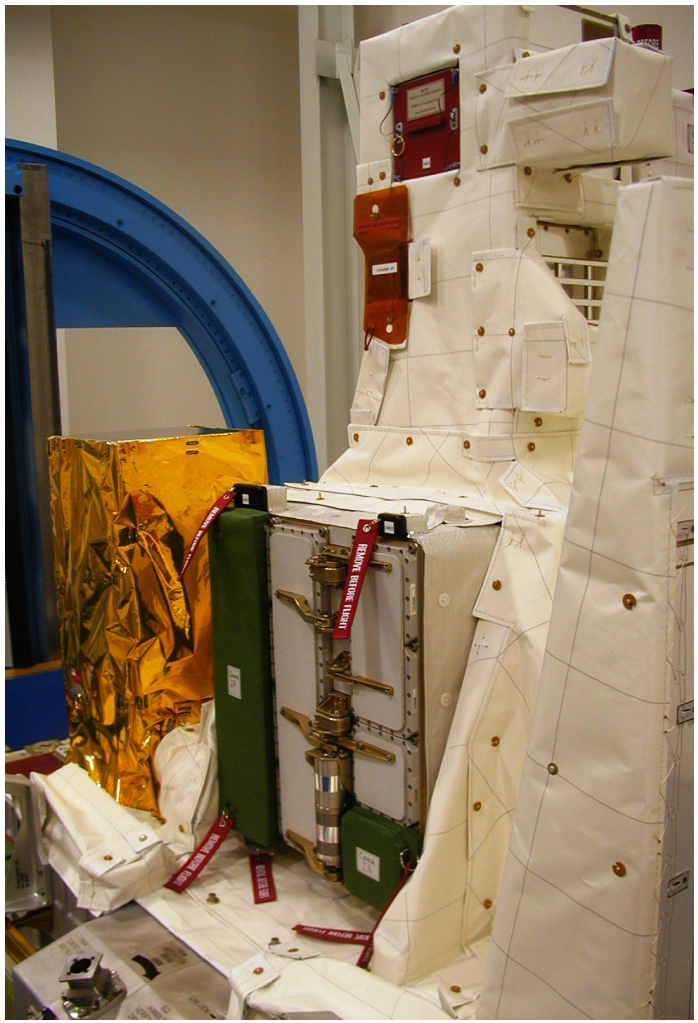
EXPOSE-E Status

Integrated on EuTEF

Flight Model
Number of samples:

Biological:	328
Chemical:	80
Dosimetrical:	64
Total:	472

+ Ground
Total: 944



EXPOSE-E Status

STS 122 Roll out

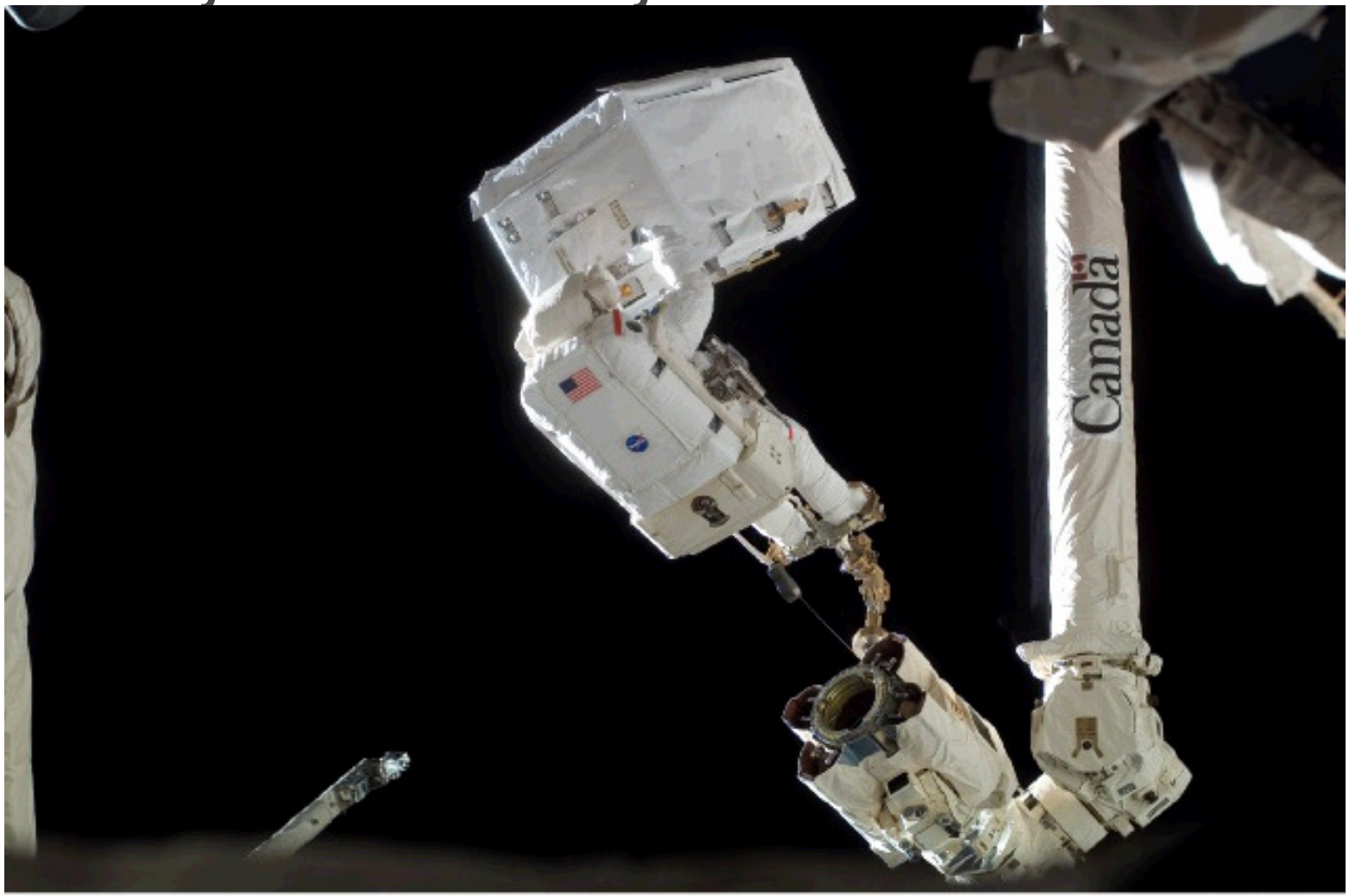
EXPOSE-E launch successful February 7th, 2008

EXPOSE-E in Space in Cargo Bay of STS 122 Atlantis

EXPOSE-E - Final Destination on Columbus

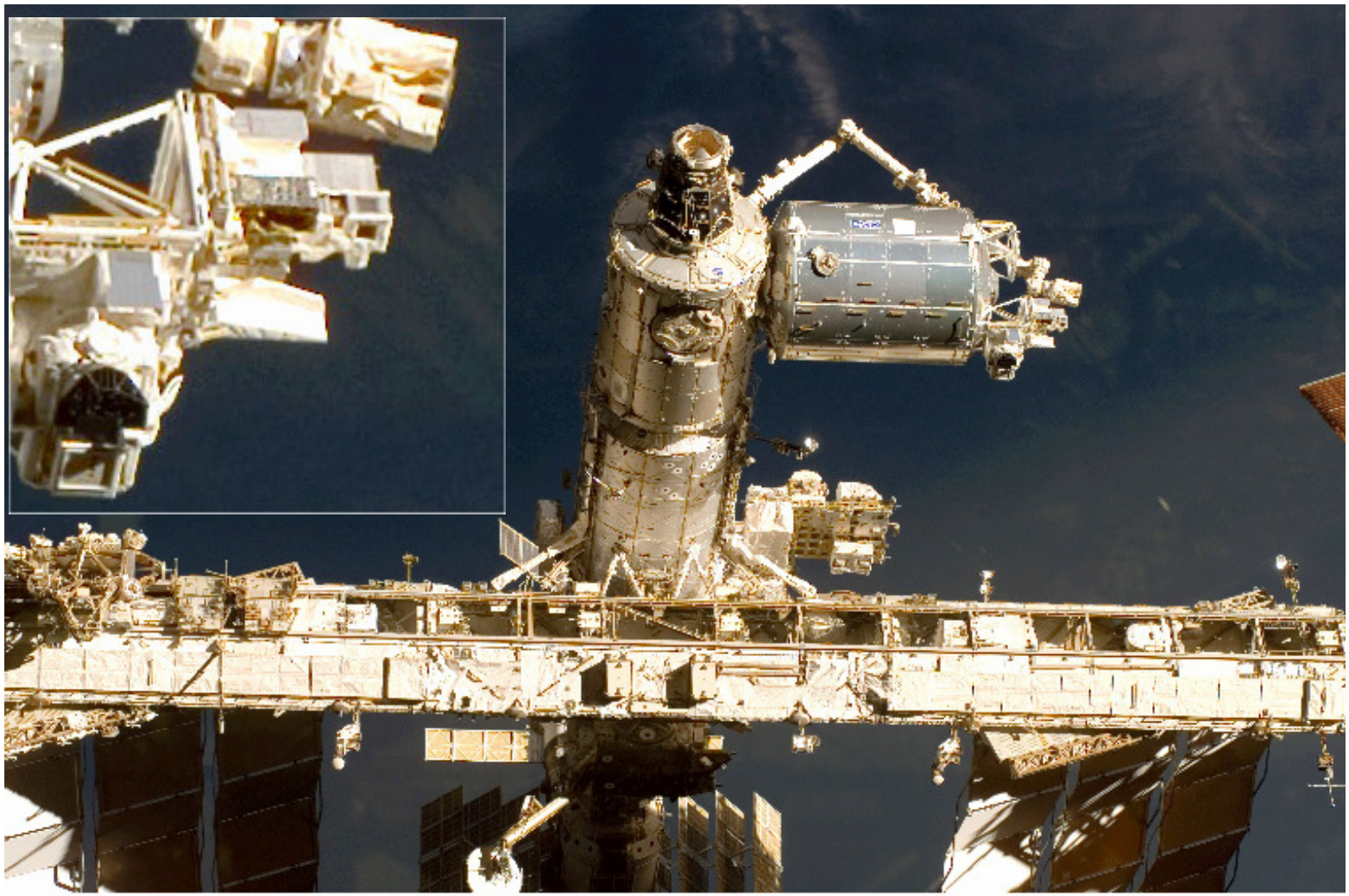
ISS016E029500

Similar to EXPOSE-E –
N_2 on its way to Columbus by Rex Walheim



S122E008149

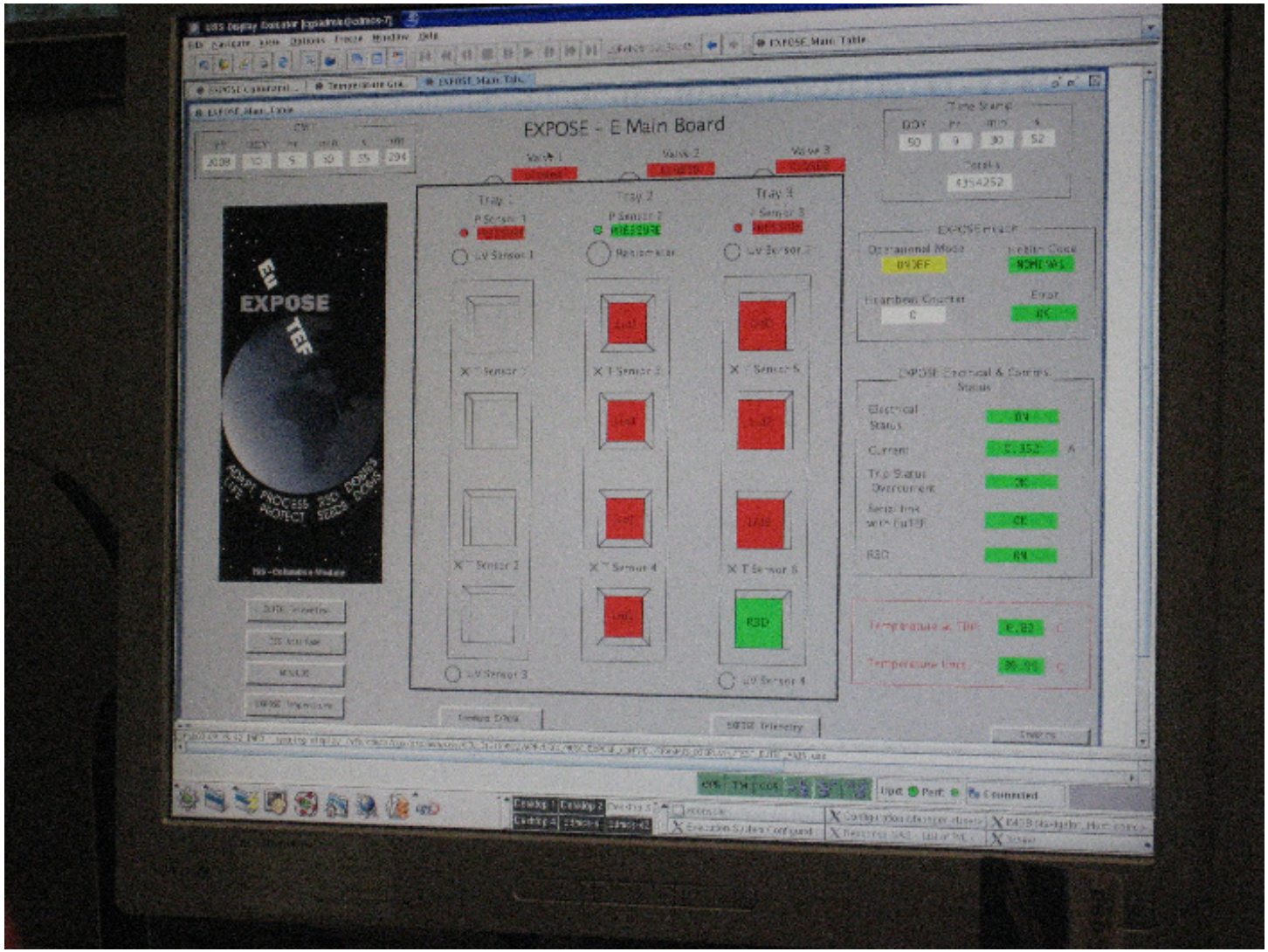
EXPOSE-E – On EuTEF on Columbus



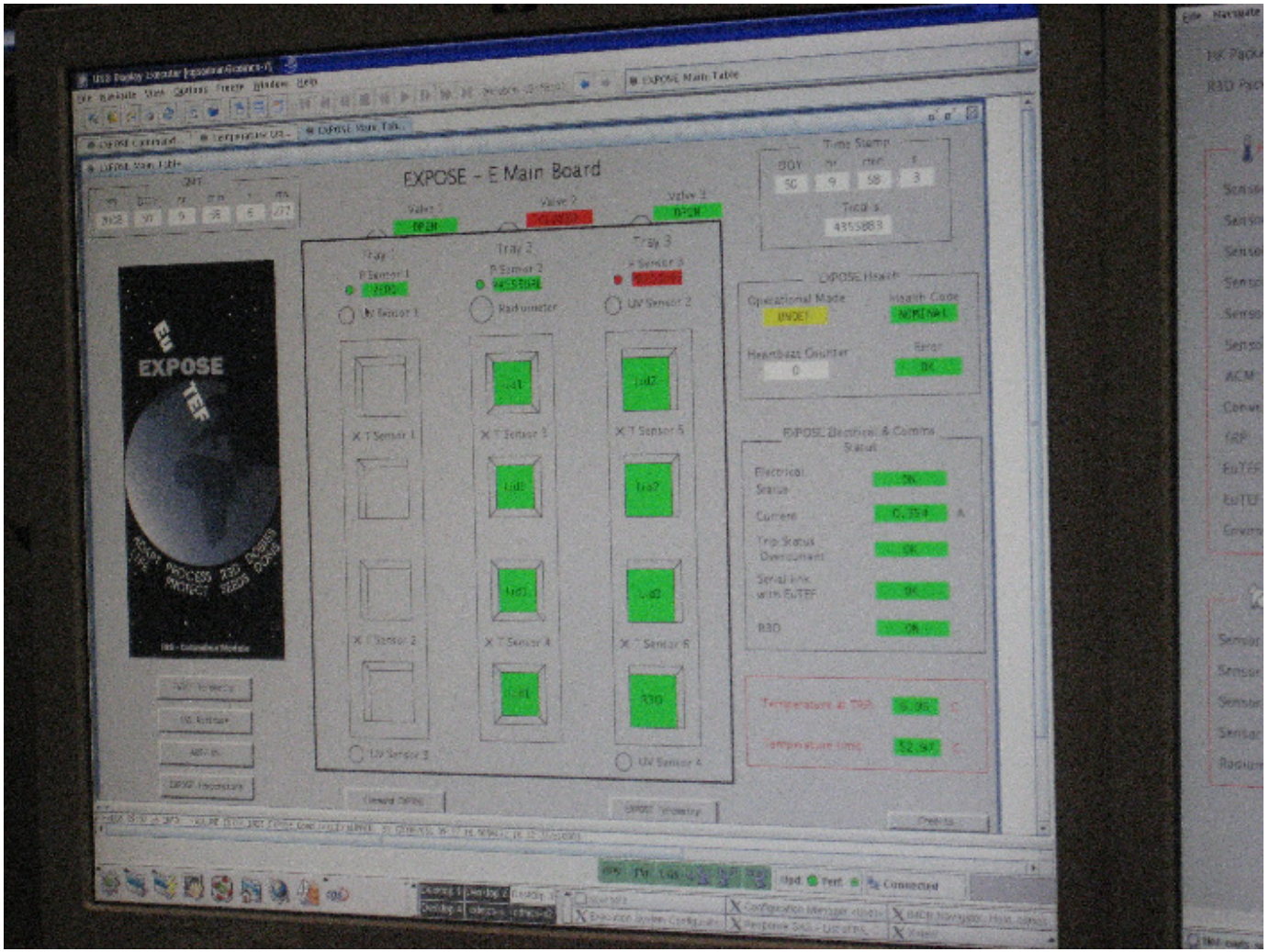
S122E009956

EXPOSE-E – COORD at MUSC DLR Control Room

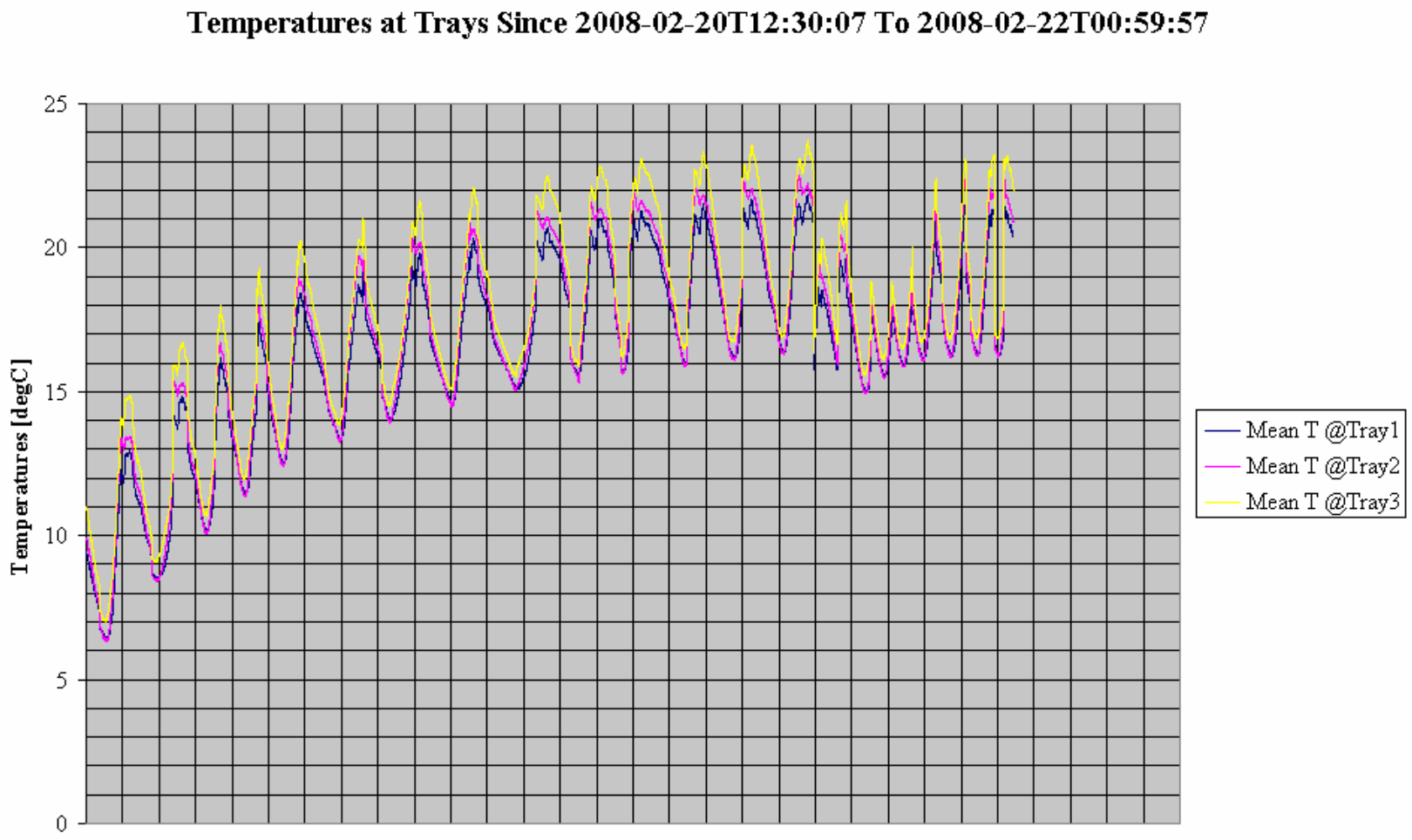
EXPOSE-E – Check Out and Commissioning….



EXPOSE-E –….successful!

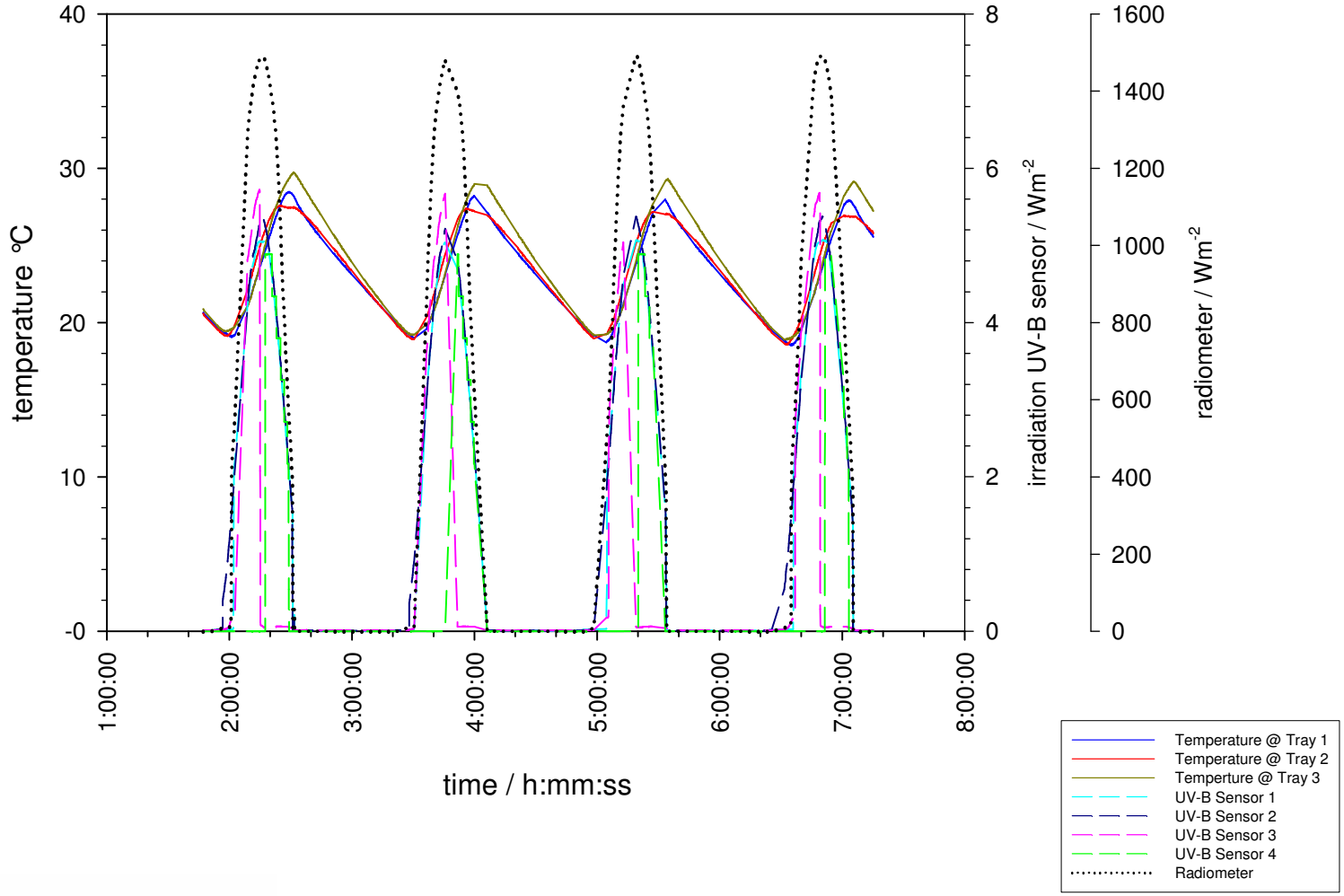


EXPOSE-E – Data - Temperature



EXPOSE-E – Mission Data – UV + Temperature

temperature and UV-B and radiation graph 2008-03-10



EXPOSE-E – Virtual Control Room

http://www.go.dlr.de/musc/expose/telemetrie.php

Thank you!