



## BACK TO THE MOON — ARTEMIS ESM EEE INSIGHTS

Dr. Frederik Küchen, Tesat-Spacecom

ESCCON 2023 Toulouse, 09.03.2023

TOGETHER TO THE MOON — WHAT A VIEW

TESAT-STANDARD



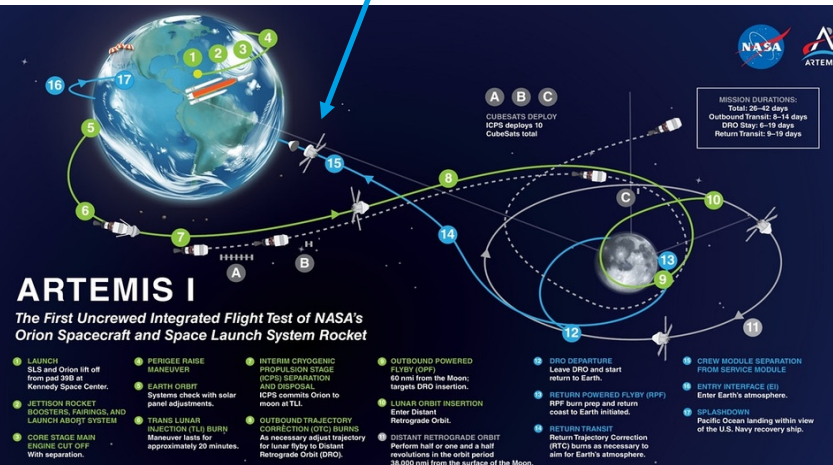


sources: dlr.de / esa.int

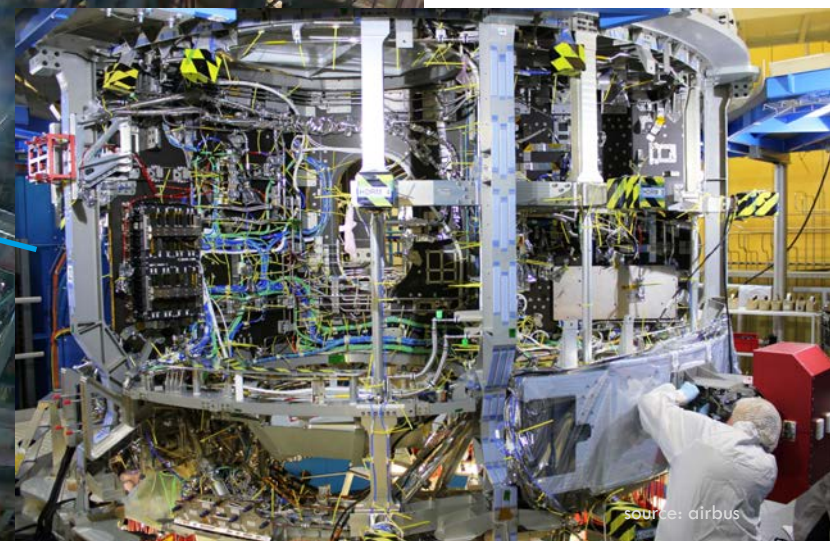
Crew Module

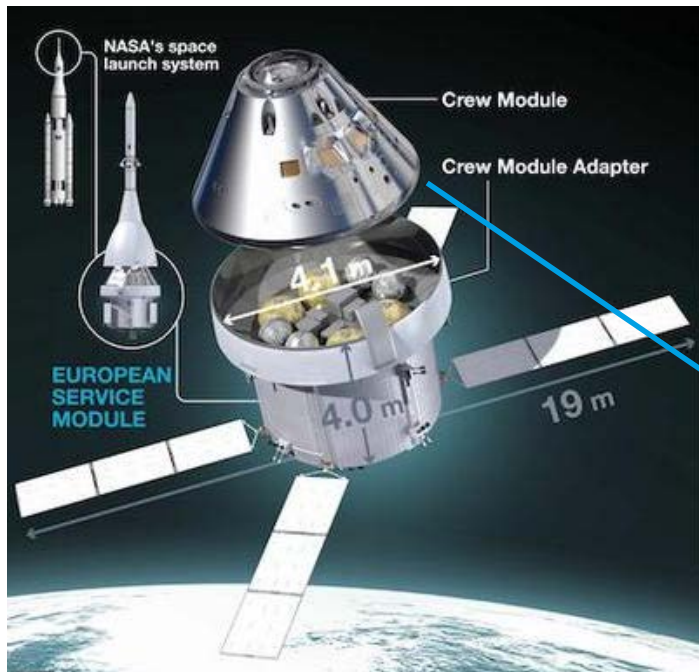
Service Module

EOL









sources: spacewatch.global

- » Orion ESM, based on ATV-5
- » Prime Contractor: Airbus Defence & Space, Bremen
- » Launch date: Nov. 16, 2022
- » Mission duration: 25 days, 10 hours, 53 minutes
- » Total distance travelled: 1,4 million miles
- » Re-entry speed: 24,581 mph (Mach 32)
- » Crew Vehicle Splashdown: Dec. 11, 2022



sources: nasa.gov



- » Main engine and electricity using four solar arrays
- » Climate and temperature regulation of the spacecraft
- » Storage and control of fuel, oxygen and water supplies for the crew

## INSTRUMENTS WITH INVOLVEMENT OF TESAT PARTS AGENCY (ESM-1):

- » PDE (Propulsion Drive Electronics) by AIRBUS DS Bremen
- » SADE (Solar Array Drive Electronics) by Thales Swiss
- » SADM (Solar Array Drive Mechanism) by Beyond Gravity (former RUAG Swiss)
- » TCU (Thermal Control Unit) by Crisa Spain
- » CMU (Command and monitoring unit) by Thales Italy
- » PCDU (Power Control and Distribution Units) by Leonardo Italy





## ATV

- » Cargo missions + ISS lift
- » Partly class 1, preferred class 2
- » Low TID/SEE requirements only
- » 23 different user involved
- » Approach f. combined procurement of packages of several vehicles limited
- »  $\approx$  300k pc. of EEE-parts per ATV vehicle
- » Engineering support started in 1998

Typical mission duration:  
< few weeks in 400km alt.

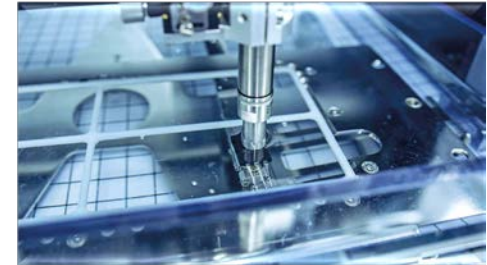
## ESM-1

- » Manned missions
- » Level class 1
- » Rad-hard devices
- » 11 different users involved
- » Strategic consolidation of part types between 6 out of 11 equipment's
- »  $\approx$  200k pc. of EEE-parts per ESM vehicle
- » Engineering support started in 2014

Planned/defined mission duration:  
months (Moon) ... 2+ years (Mars)



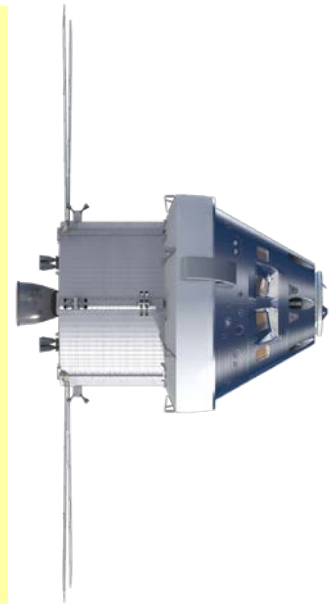
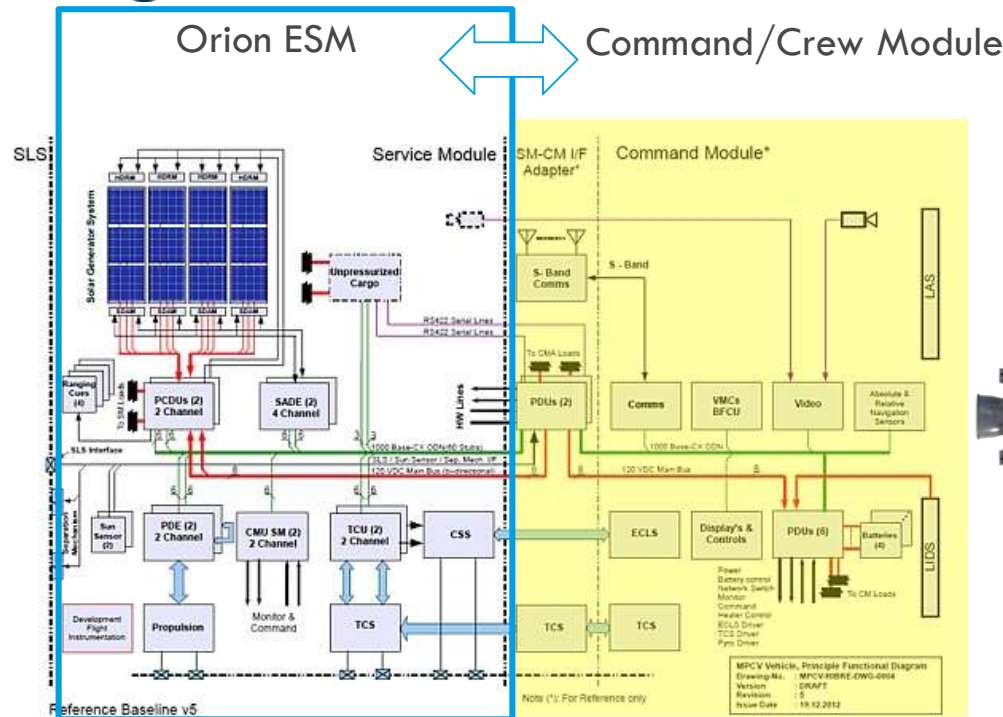
- » In total 20,000 different electrical and mechanical components types for one ESM, plus 12 km of cables.
- » EEE Components Key Facts (until ESM-6):
  - 80 DCL updates successfully implemented (most early phase)
  - 45 successfully passed RVT's
  - 150 PADs fully agreed and signed
  - 300 successfully passed DPA's
  - >540 consolidated line items between 6 equipment's







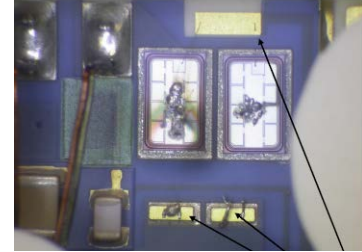
- » 2014:  
Operation Conditions for  
PDE DCDC Conv.: 100-  
100V
- » 2016:  
Update, LM CCM request  
to DCDC Conv. to 120V.  
→ Stretched the selected  
DCDC range
- » Way forward:  
Testing campaign of  
actual DCDC Conv. or to  
look for an alternative  
DCDC Conv.



source: ESA, Airbus DS, <https://www.eoportal.org/satellite-missions/artemis-i#esm-european-service-module>

**Finding:**

In 2016 one (of 48) Hybrid DCDC failed Group C life test burn-in (924hrs from 1000hrs).  
Two MOSFETs of Input Section, both burned.  
After replacing the MOSFETs, the Hybrid worked again – no other parts affected.

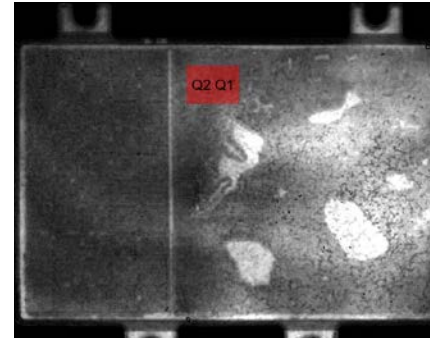
**Root Cause:** insufficient substrate to header attachment

- the thermal resistance increased during life test (substrate attachment got worse, more delamination) and forced the internal MOSFETs into thermal runaway.
- the MOSFETs were too hot ( $+300^{\circ}\text{C}$ ) for a too long time (weeks) and diffusion processes lead to higher power consumption and finally the MOSFETs burned.

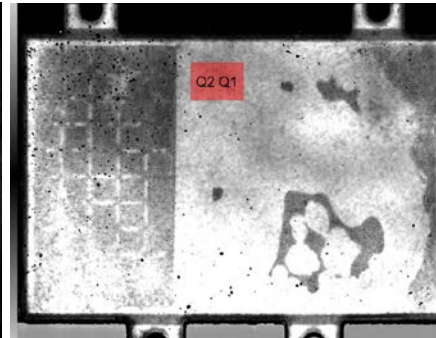
**CSAM of all Units**

8 parts of 48 were sorted out.

Typical Voiding  
30% max.

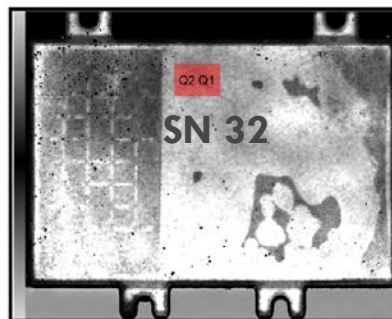
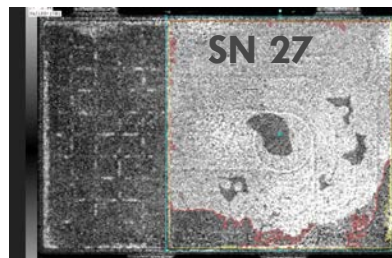


Over 80%  
Voiding

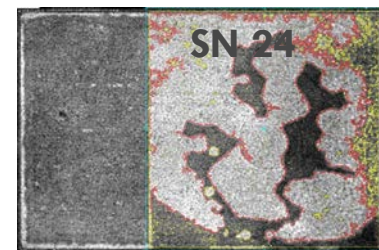
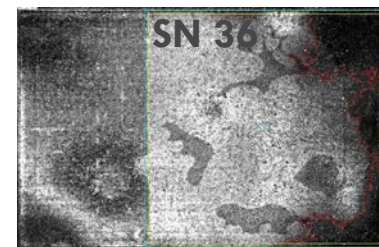
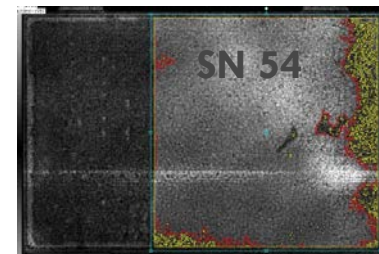


→ tests on worst-case de-selected CSAM samples

Serial No	Void (%)
32	83,34
54	79,04
36	82,68
24	65,25
27	72,26



■ SN032 – Group C2 failure





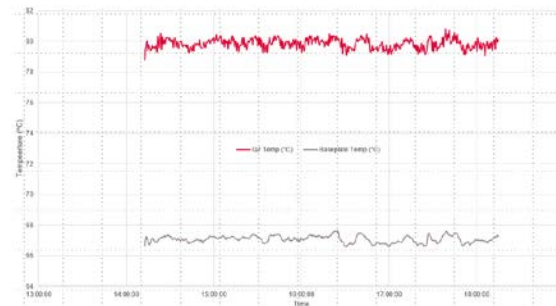
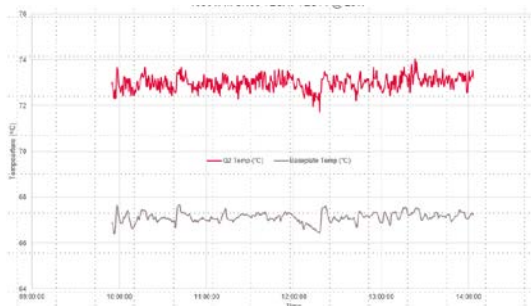
## TEST SETUP BY TESAT AND MANUFACTURER (TEST 1)

### Test 1: Investigate max temperature for internal MOSFET in equipment max. operating conditions

Success criteria: MOSFET temp stays well below max operating temp of MOSFET spec ( $175^{\circ}\text{C}$ ).

→ no diffusion processes, no weakening of substrate attach through high temperature.

- de-lid DCDC; controlled base-plate; thermo camera for 4 hours, at 28W, 60W and 110W
- MOSFETs max surface temp maximum was  $73^{\circ}\text{C}$ ,  $81^{\circ}\text{C}$  and for 110W  $101^{\circ}\text{C} \ll 175^{\circ}\text{C}$

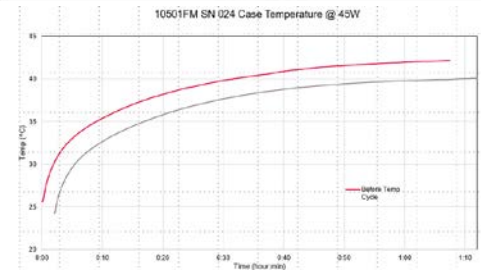
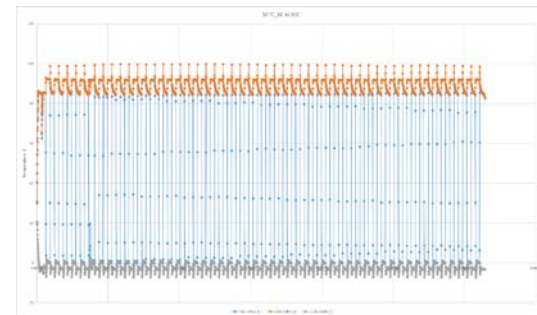
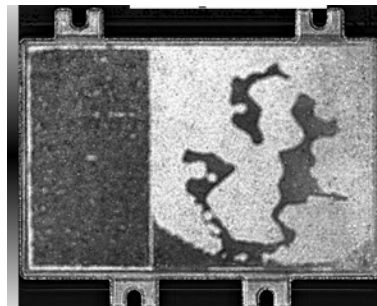
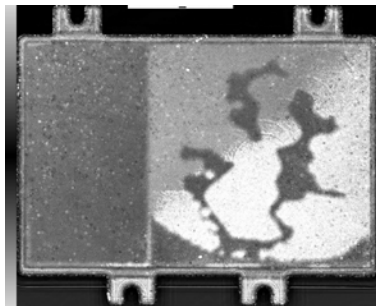


## Test 2: Check Stability of Substrate Attachment and Thermal resistance with temp cycles

Success criteria: plots and pictures before and after temp cycles are nearly identical, very little degradation of attach.

- Operate part with 45 Watts, start at room temperature, and measure case temperature per min for 1 hour
- Thermal Shock Chamber: apply temp cycles on non operating part: 50 cycles 0 to 80 °C, (gradient 15 K/min)
- repeat a)
- Compare CSAM and curves

■ **Stability of substrate attachment and thermal resistance confirmed**



- » One of 48 DCDC under changed 120V parameter (beyond spec) showed finding in Group C
- » Root cause analysis made
- » Insufficient substrate to header attachment, thermal heat dissipation
- » With mission related max parameters (hours in operation, power etc.) and beyond more tests were performed on wc units

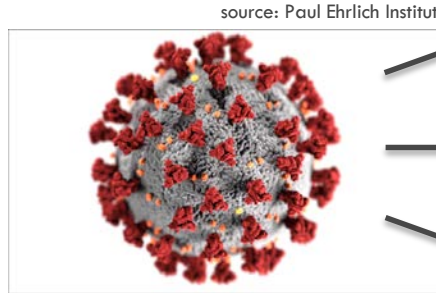


**Joint Decision to go forward with this  
Radiation Hardened DCDC Converter.**

- » Further actions: Substrate to header attachment was improved manufacturer
- » Manufacturer developed a screening procedure for sono scan inspection for all future lots and enhanced assembly reports, Pre-cap, Group tests incl. Life test, FCSI etc



- » “Parameter changes of its own” in 2020...2022
- » EEE Supply times 80++weeks
- » Price increases
- » Partial contract fulfillments
- » Sometimes stops in suppliers quoting
- » Component quality issues
- » Unclear supplier strategies



## » Tesat for Orion ESM:

- » Work as team, joint efforts by all disciplines
- » 94% on-time deliveries for our ESM contribution
- » 15% improvement of lead time especially for critical Items

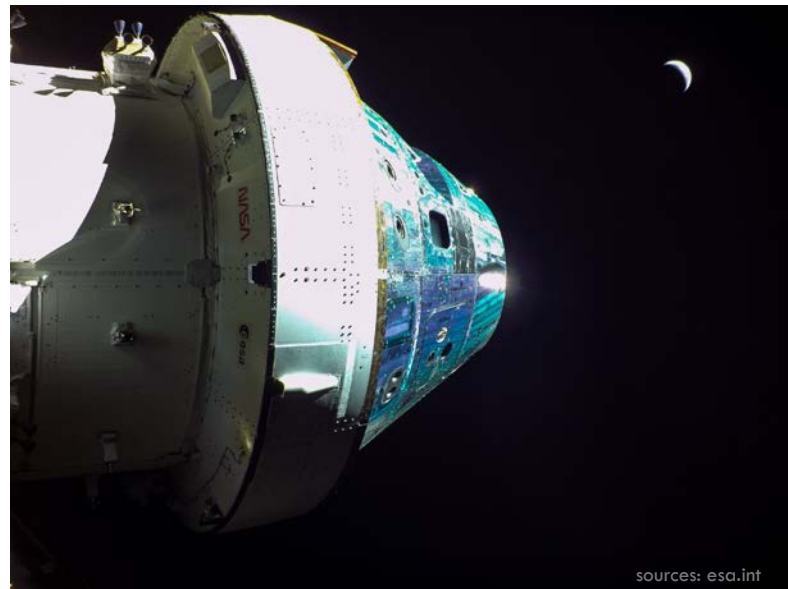
Price stability

Delivery reliability

Quality



- » Parameter changes in projects (even late) can occur
- » Part of our reality especially in new products/missions
- » Deviations/findings can be a consequence
- » Analysis expertise to work out root cause and actions
- » Teamwork and joint efforts by all disciplines



Tesat Parts Agency was the interface between customer and manufacturer – successful partnership. Joint EEE-Engineering, Testing, Quality, User and Manufacturer performance solved the problem.



# THANK YOU!