Space Debris Research at DLR

SOLID-A solar panel based impact detector

DLR Institute of Space Systems Bremen, Germany

Dr. Waldemar Bauer

Space Environment Situation

- High collision probability with small objects (diameter > 100 µm)
- Degradation or significant damage of spacecraft / payload expected
- Available measurement data is insufficient

Small Objects Validation			
MASTER2009		**ORDEM2000**	
LDEF	LEO	STS Windows/Radiator	LEO
EuReCa	LEO	EuReCa qualitatively	LEO
HST-SA (SM1) HST-SA (SM3B)	LEO	HST-SA	LEO
		MEEP qualitatively	LEO

Ref.: Flegel et al. 2011; Liou et al. 2002

Spacecraft	Mission			Orbit		Area
	$Start$	End	$D_M\ (days)$	$h\ (km)$	$i\ (°)$	$A_T (m^2)$
LDEF	06.04.1984	12.01.1990	2106	475	28,5	151
HST (SM1)	24.04.1990	08.12.1993	1320	614	28,5	62
EuReCa	01.08.1992	24.06.1993	326	495	28,5	131
HST (SM3B)	04.12.1993	03.03.2002	3011	614	28,5	120

Ref.: Flegel et al., 2011, Liou et al. 2002, UN Report 1999.

Today´s measures taken regarding Space Debris mitigation are insufficient!

In-situ measurement sensors required to close the data gaps!

DLR

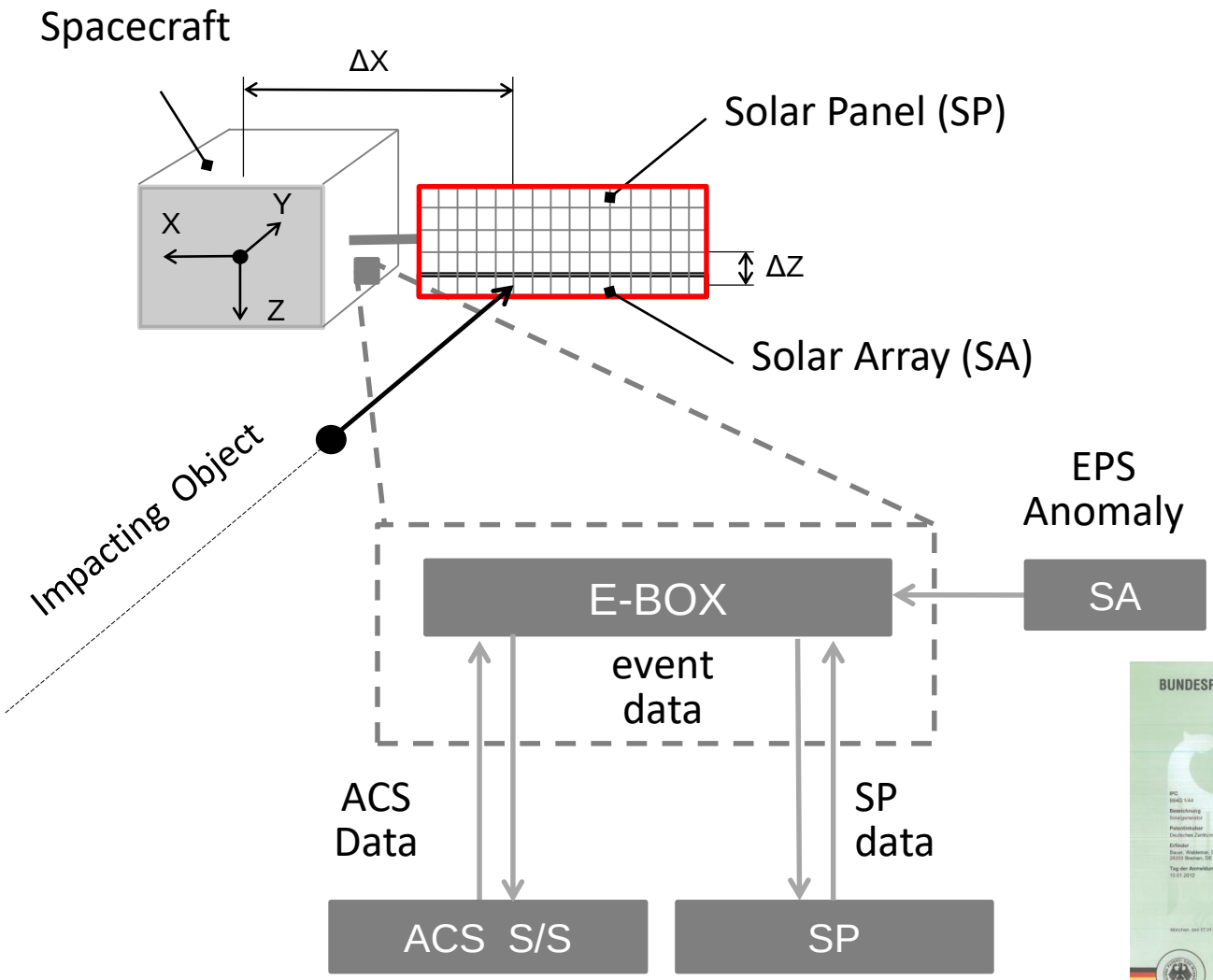
Vision: Sustainable Space Environment

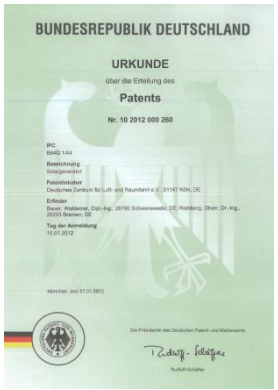
Primary Aim of SOLID Method:

Contribution to Sustainable Space Environment

- Standard application to all S/C with solar panels (mass < 200 g/m²)
- Achieve high spatial coverage (S/C constellation in different orbits)
- Provide sufficient data e.g. for software validation
- Validated software contributes to the development of sustainable space systems

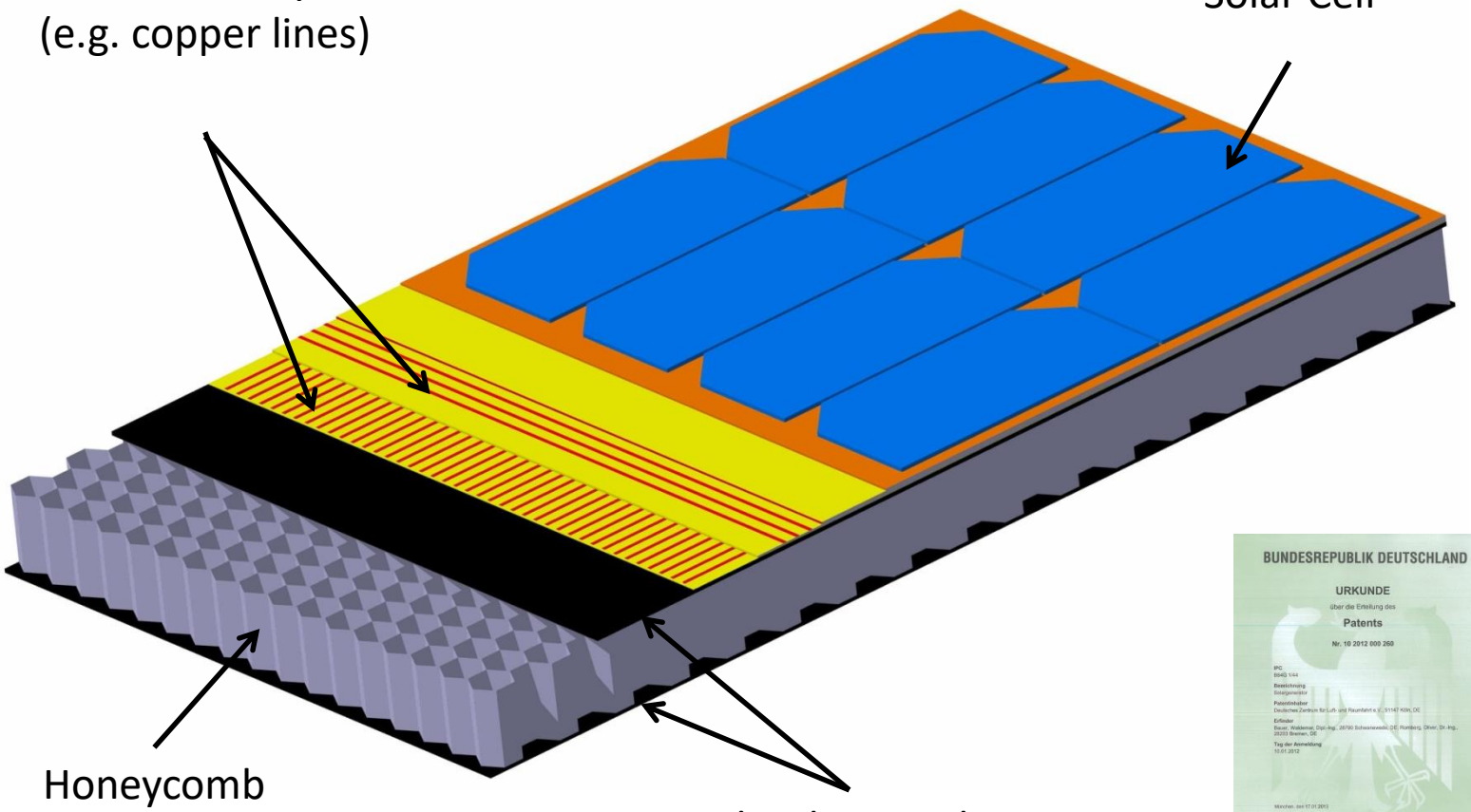
Solar panel based Impact Detector (SOLID)





Patents: DE102012000260, US8593165B2

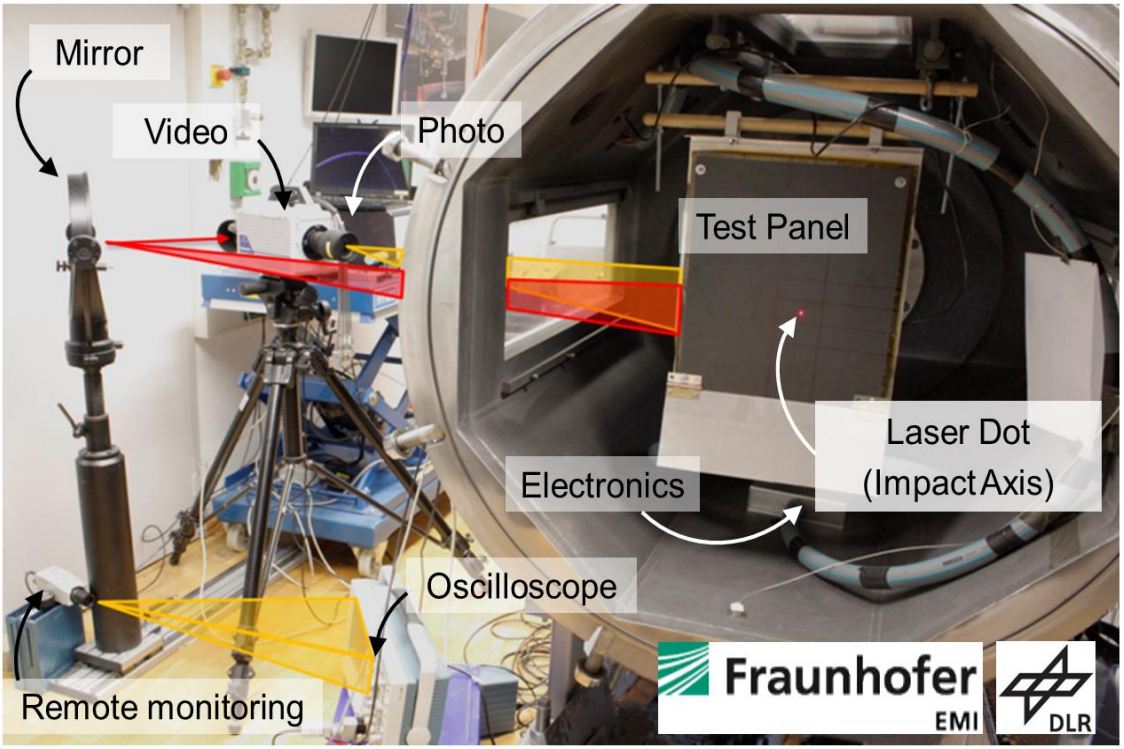
Solar panel based Impact Detector (SOLID)

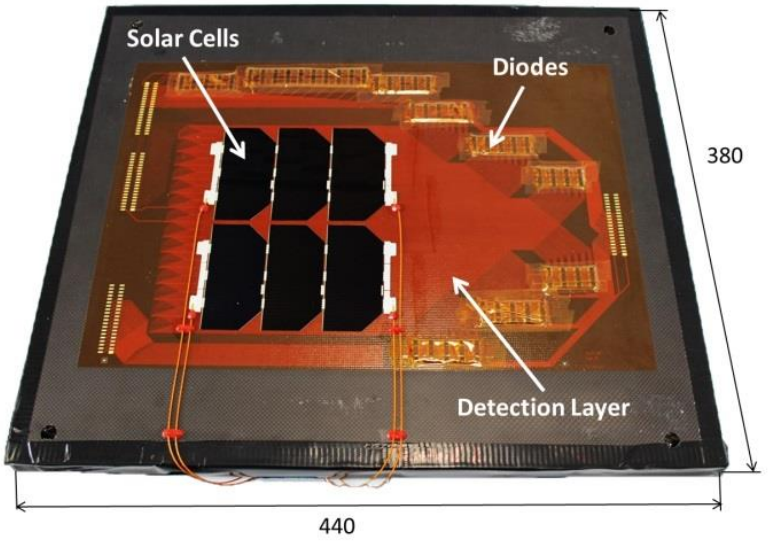


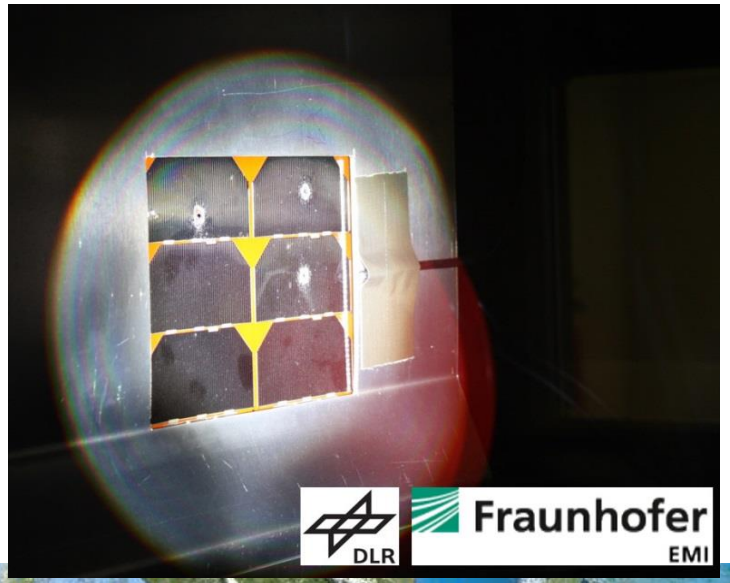
Patents: DE102012000260, US8593165B2

Impactor Diameter estimation based on ESA damage equations (HST/EuReCa)

SOLID HVI Testing







HVI-Ground Testing in 2013:

- Damage Size Analysis
- Power Supply Disturbance Analysis

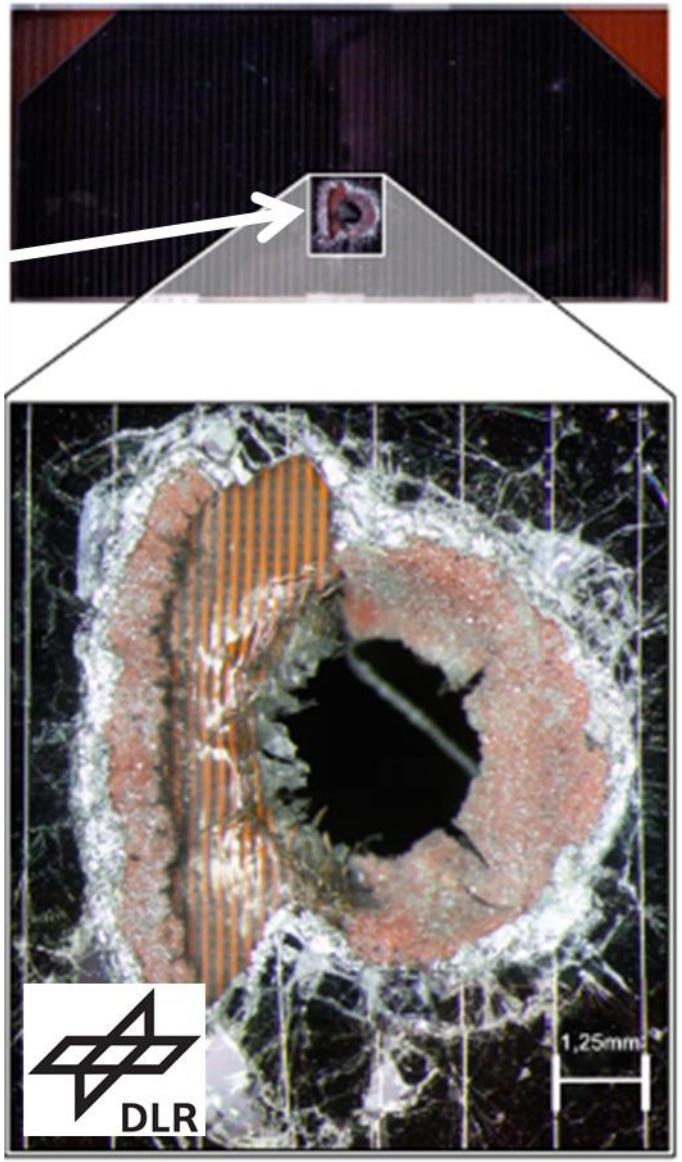
DLR

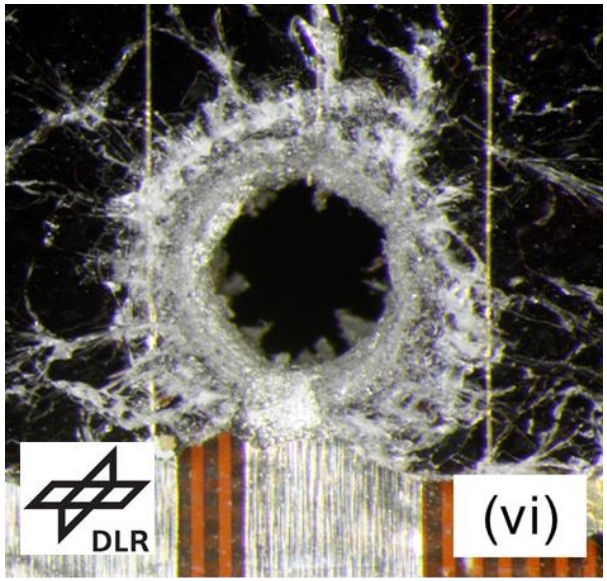
SOLID HVI Testing

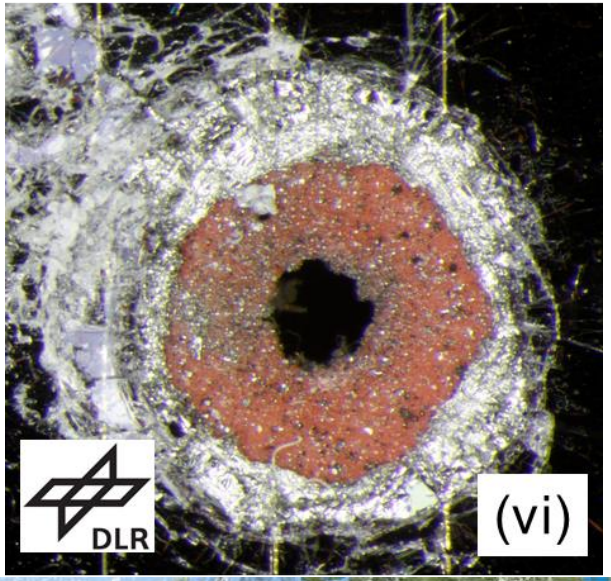
DLR

HVI Damages on SOLID Detector

Al 2017
Ø ~ 1.5 mm
v_p~ 5 km/s







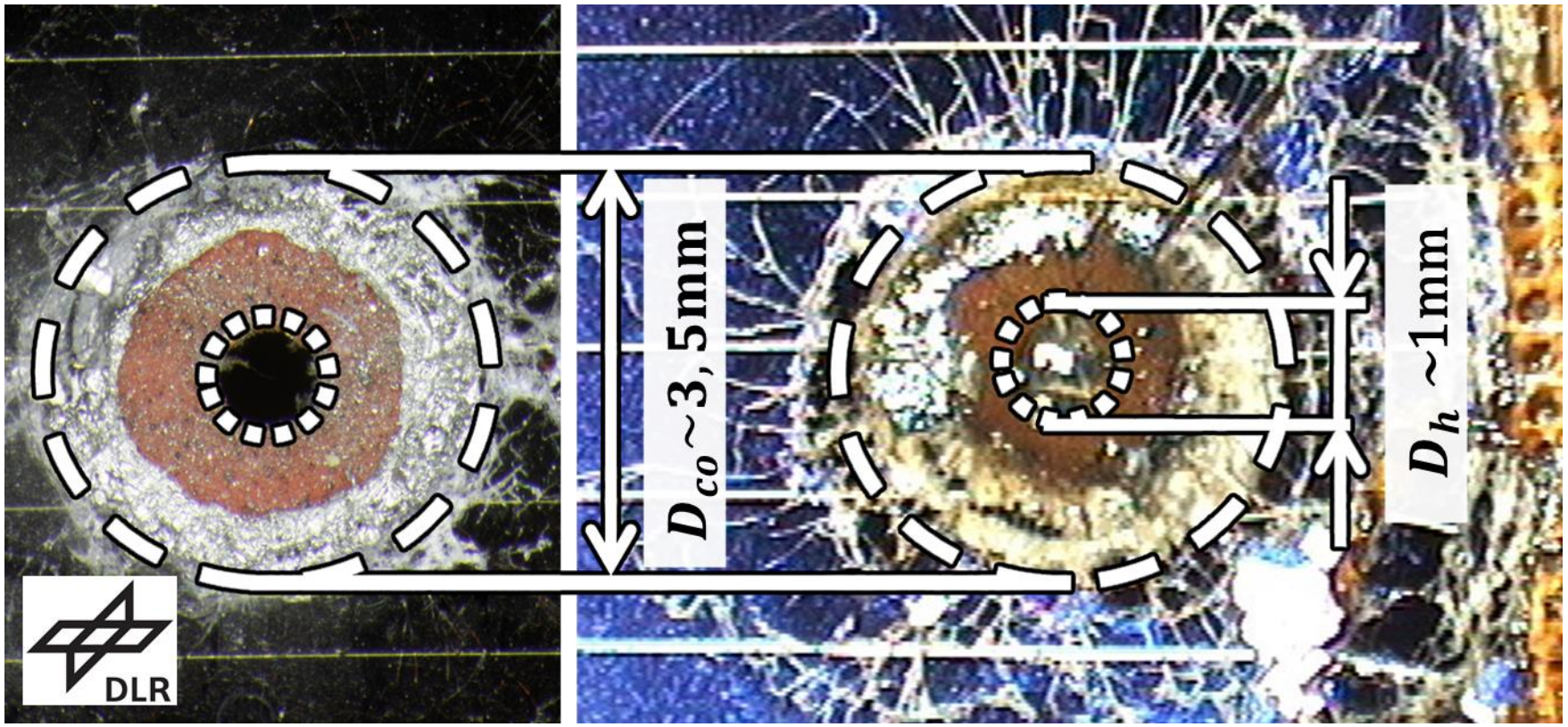
Glass,
Ø ~ 500 µm,
v_p~ 4 km/s

DLR

Damages on SOLID and HST Solar Panels

Solar panel based
Impact Detector (SOLID)

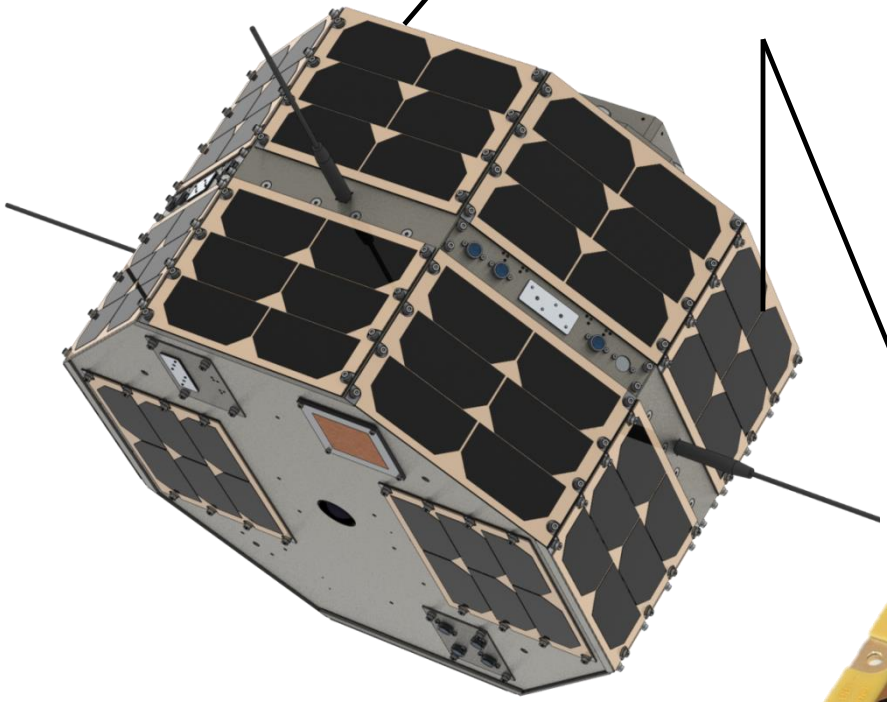
Retrieved Solar Cell of
Hubble Space Telescope (HST)

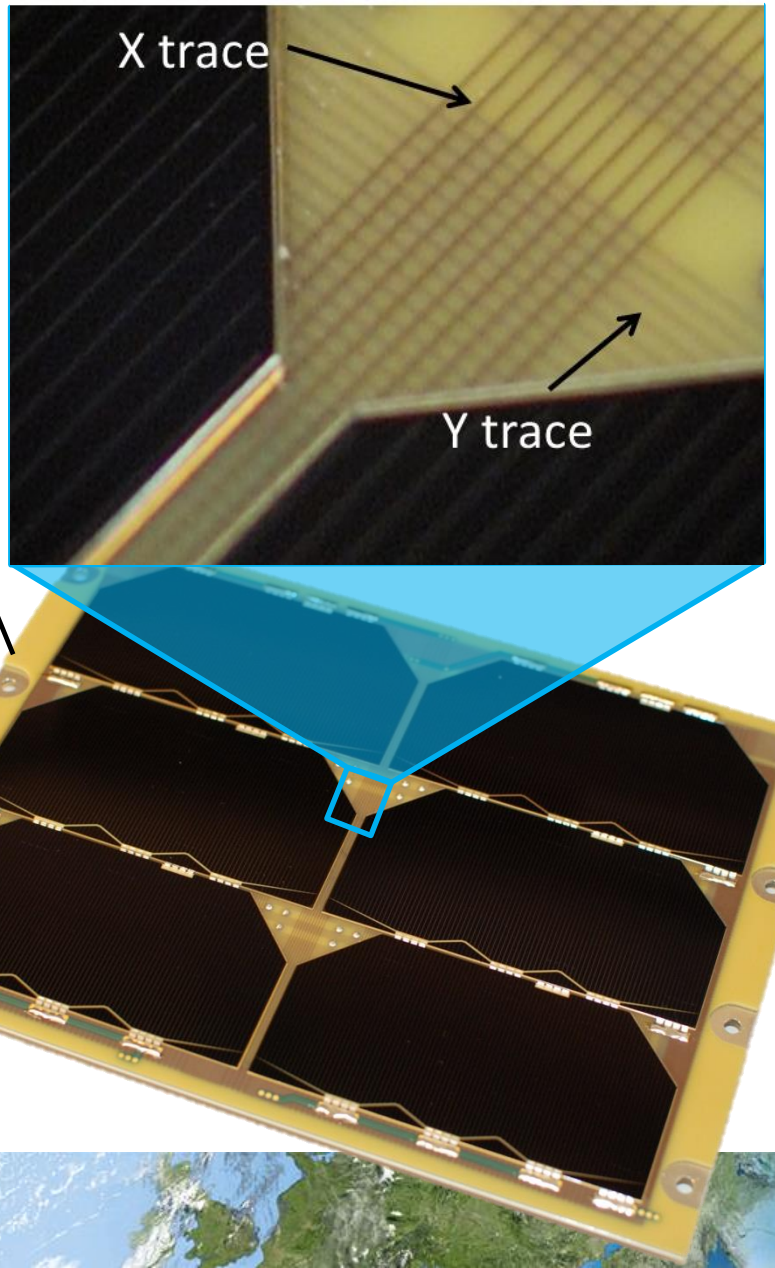


DLR

SOLID on TechnoSat Mission

Solar panels with
SOLID-Technology





S/C Dimensions: 465 x 465 x 305 mm³
S/C Mass: ~ 20 kg
Detection Area: ~ 0.08m² (4x 160x120mm²)

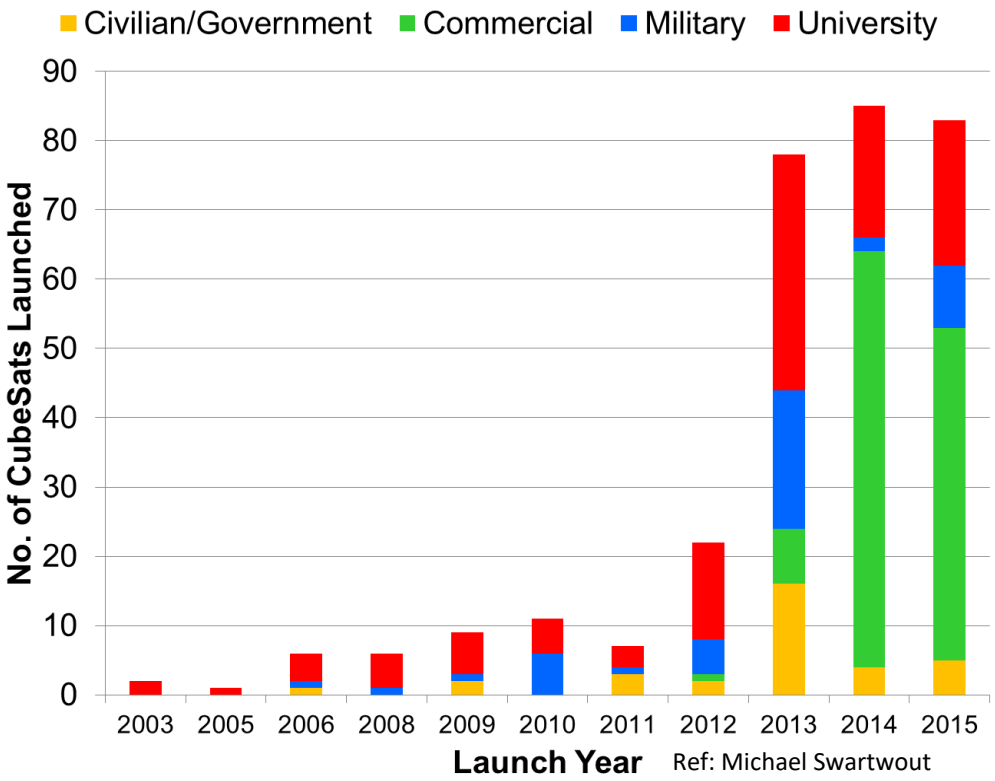
DLR

Upcoming Research

- Planed launch: 2024
- Solar panel area: ~ 3m²
- Status: feasibility study ongoing

SOLID Implementation to small S/C (example CubeSats)

CubeSat by contractor type



CubeSats by country

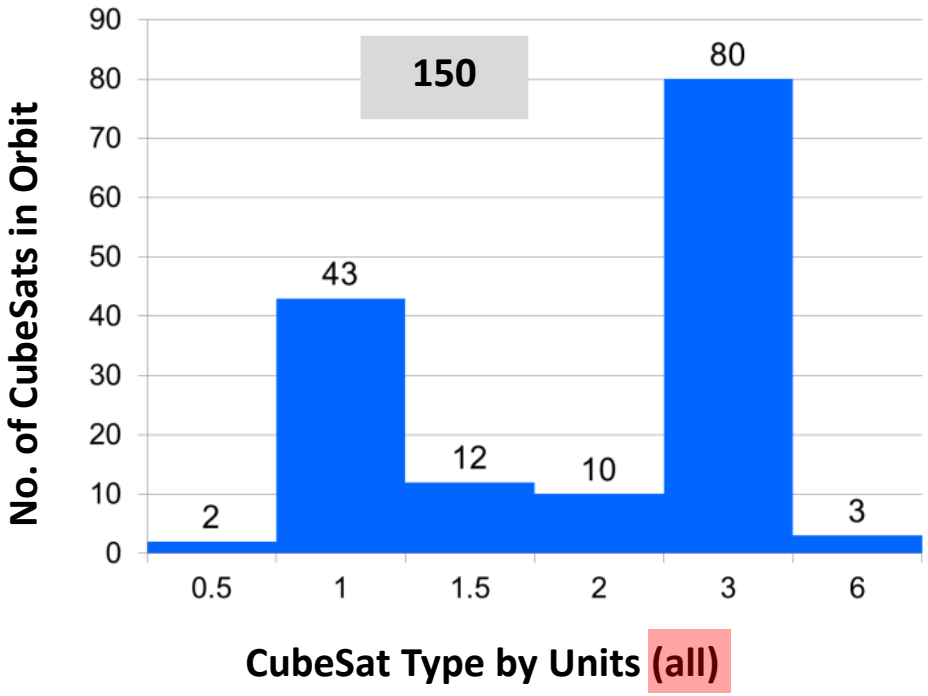
Country	Launched	Active	Country	Launched	Active
USA	220	42	Israel	1	1
Japan	19	2	Norway	1	0
Germany	7	4	Pakistan	1	0
Denmark	6	3	South Africa	1	1
Singapore	6	2	Ukraine	1	1
UK	5	2	Estonia	1	0
Brazil	3	0	Uruguay	1	1
Spain	3	1	Iraq	1	1
Peru	3	0	South Korea	1	0
China	3	0	Greece	1	0
CIS	2	2	Romania	1	0
Netherlands	2	1	India	1	1
Switzerland	2	1	Taiwan	1	0
Ecuador	2	1	Hungary	1	0
Argentina	2	2	Austria	0	0
Turkey	2	0	Belize	0	0
Lithuania	2	0	Australia	0	0
Vietnam	2	0	Finland	0	0
Belgium	2	2	Colombia	0	0
Italy	2	0	Czech Republic	0	0
Canada	2	1	Portugal	0	0
Poland	1	0	UAE	0	0
France	1	0	**Total**	313	72

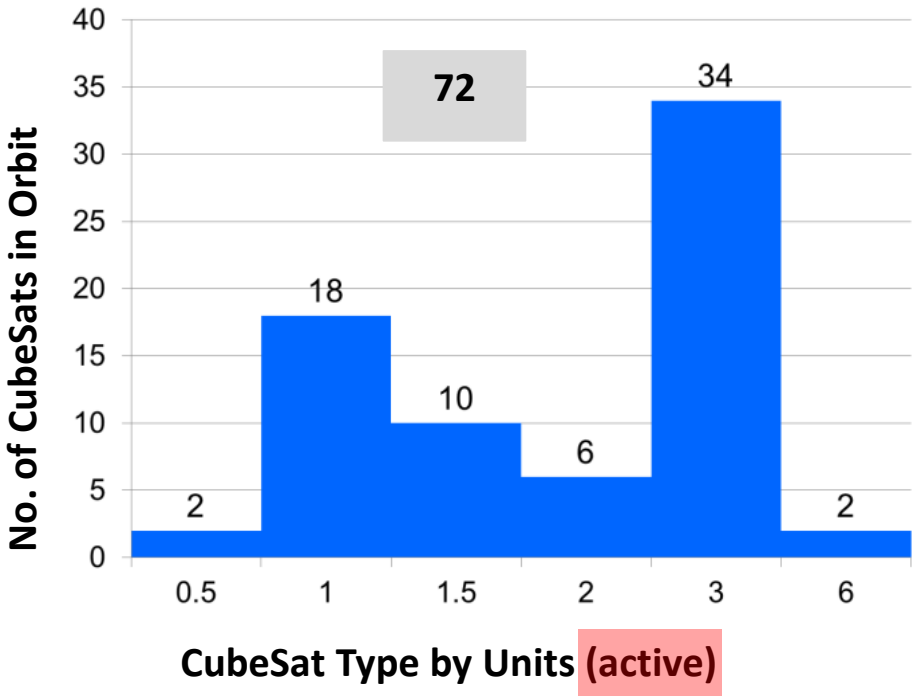
Utilized sources:

- NORAD TLE; SATCAT
- Michael Swartwout CubeSat database
- UCS satellite database
- Gunter's Space Page CubeSat database

Ref.: Bauer, W., et al., "Debris in-situ Impact Detection by Utilization of Cube-Sat Solar Panels," Valletta, Malta, May 2016

Detection Area estimation (w/o demised, April 2016)





Currently available total solar panel area of active CubeSats in orbits ca. **6.1 m²** !

Ref.: Bauer, W., et al., "Debris in-situ Impact Detection by Utilization of Cube-Sat Solar Panels," Valletta, Malta, May 2016

Retrieved Solar Panels

Retrieved solar panels of HST and EuReCa

Spacecraft	Mission			Orbit		Area	
	$Start$	End	D_M (days)	$h\ (km)$	i (°)	$A_{SZ}(m^2)$	
HST (PFA1)	24.04.1990	08.12.1993	1320	614	28,5	20,73	~ 5.7 m² p.a.
HST (PFA2)	04.12.1993	03.03.2002	3011	614	28,5	41,46	~ 5 m² p.a.
EuReCa	01.08.1992	24.06.1993	326	495	28,5	20,04	

FPA = Post Flight Analysis, D_M = mission duration, h = altitude, i = inclination, A_{SZ} = total analysed solar panel area
Drolshagen1997, 2002; Flegel2011; McDonnell2005, 2009

Estimated total detection area of active CubeSats is 6.1 m²

Advantage:
real-time in-situ measurement data from different orbits !

Ref.: Bauer, W., et al., "Debris in-situ Impact Detection by Utilization of Cube-Sat Solar Panels," Valletta, Malta, May 2016

DLR

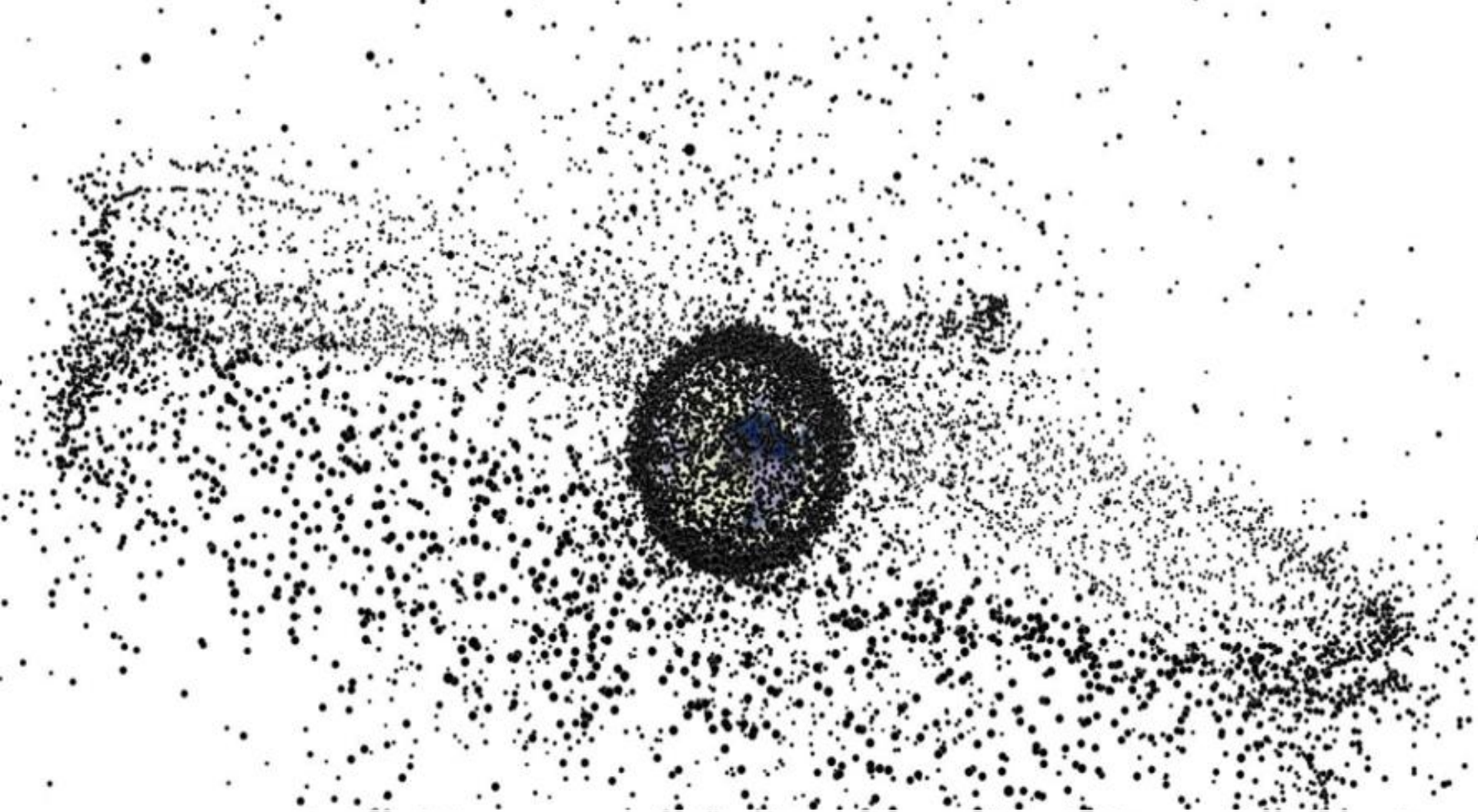
Conclusion / Outlook

- HVI-Test results on “SOLID” detector fits with ESA developed damage equation
- Detection method “SOLID” is able to provide real time data for objects with diameter of 70 µm up to ~ cm,
- OOV of SOLID: TechnoSat, CompactSat (Upcoming)
- Future application on small and large S/C is intended!

Primary Aim of SOLID Method:

- Standard application to all S/C with solar panels (mass < 200 g/m²)
  - Achieve high spatial coverage (S/C constellation in different orbits)
  - Provide sufficient data e.g. for software validation
  - Contribute to the development of sustainable space systems

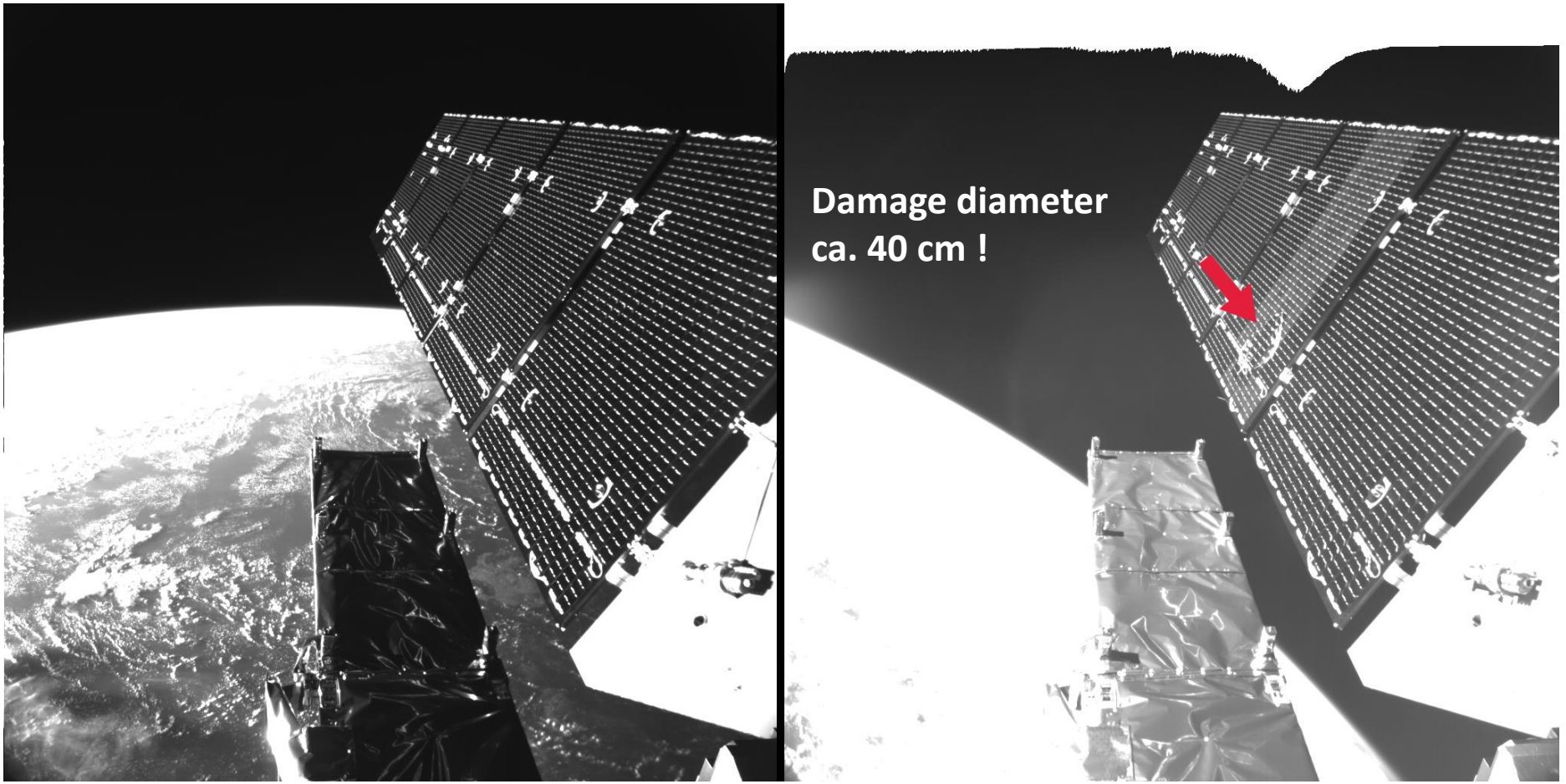
DLR



Thank you for your interest!

DLR

Damage Examples on Sentinel-1A Solar Panel

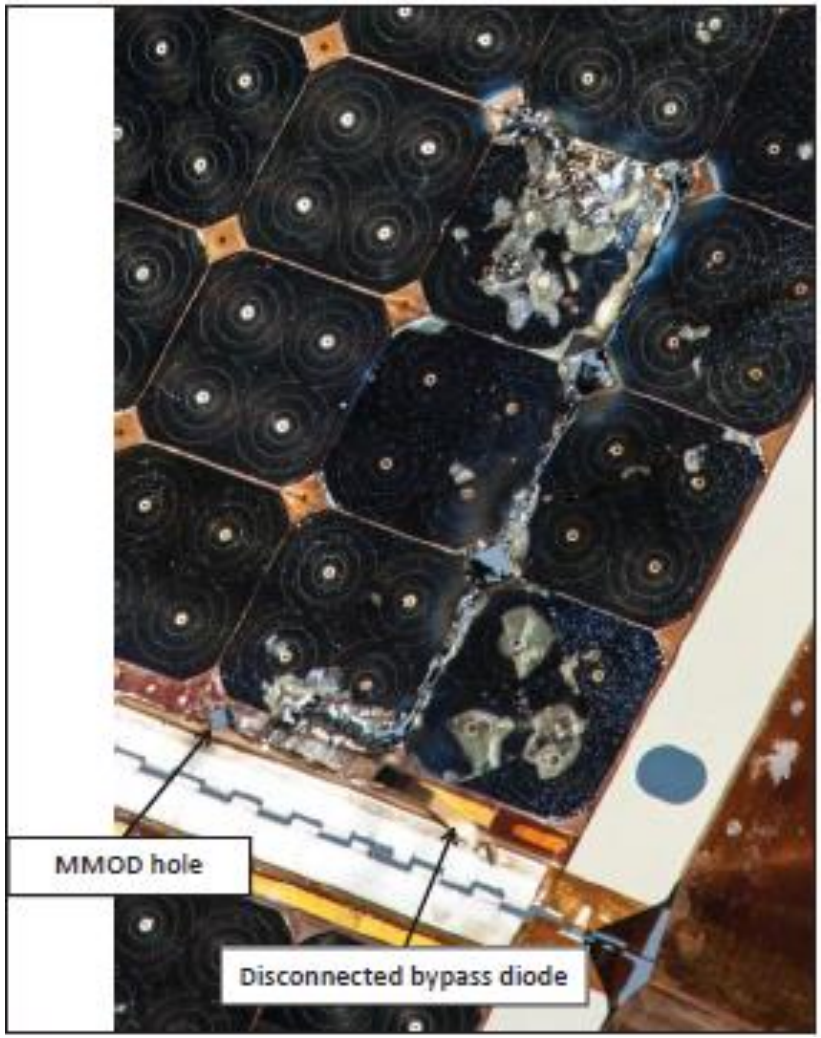


Millimetre-size particle hits on 23 August 2016 Copernicus Sentinel-1A satellite solar panel

Ref: http://www.esa.int/ESA

DLR

Damage Examples on ISS Solar Panels



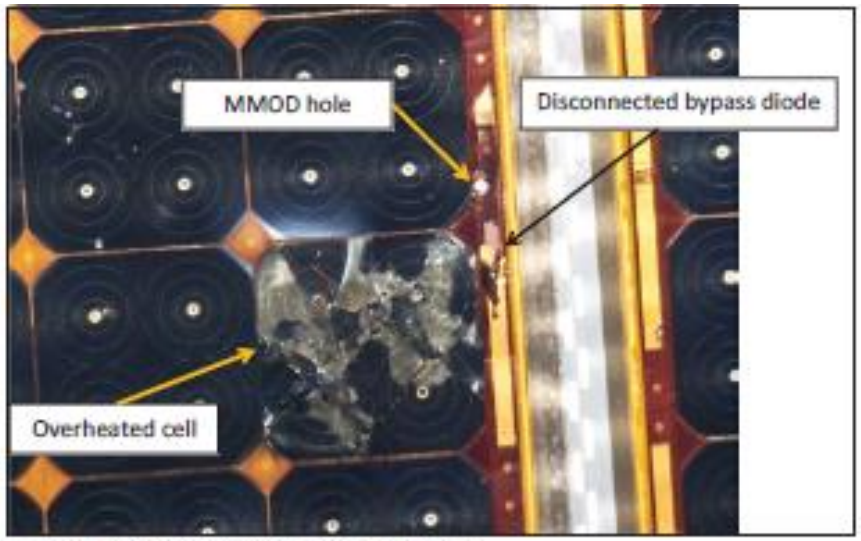


Figure 6. ISS Solar Array 2A, panel 6B damage.

Ref.: Orbital Debris Quarterly News, Volume 18, Issue 4

DLR