33. FED-Konferenz
24./25. September 2025 Lübeck

Entwicklung einer Deep-Space-Elektronik für ein optisches Instrument zur Venus-Kartierung

25.09.2025

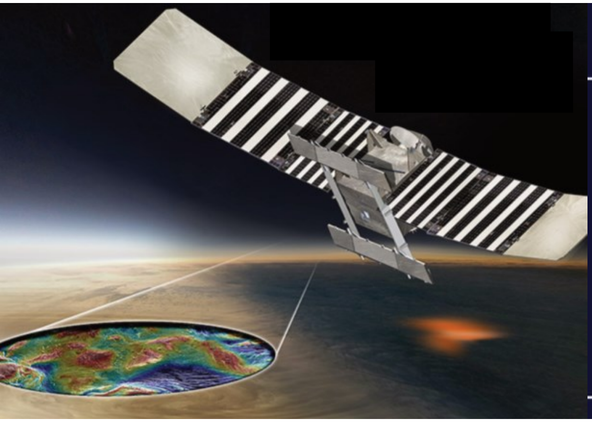
Fitzner Alexander
DLR – Institute für Weltraumforschung

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

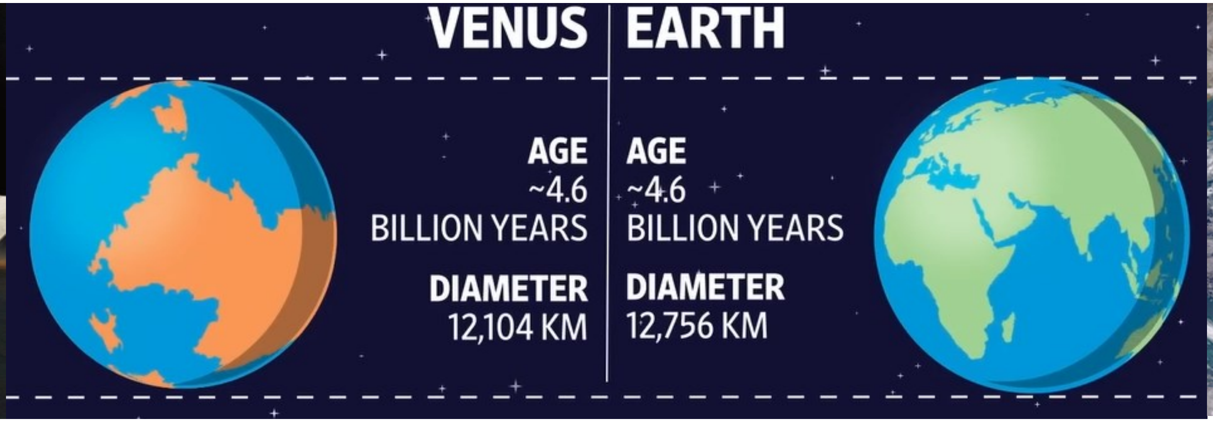
- General introduction to the Veritas & EnVision Missions
- The Instrument – VEM/ VenSpec-M
- VEM/ VenSpec-M Electronic
- PCB Assembly & Manufacturing for Space
- EEE Components selection for Space

Why is Venus so different from Earth?

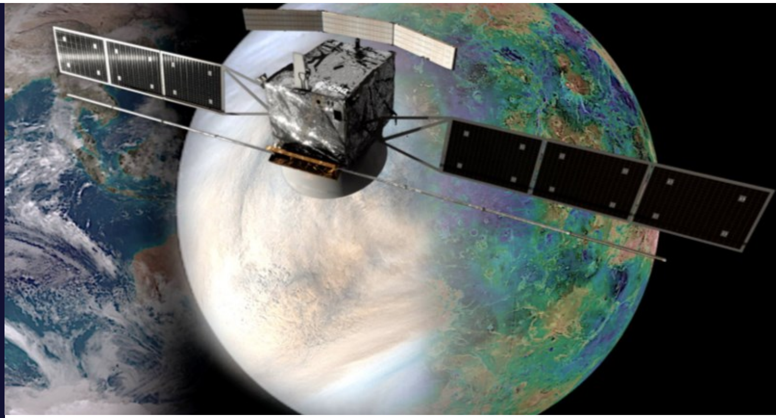
- **History - How have the surface and interior evolved?**
  - **Activity - How geologically active is Venus?**
    - **Climate - How do geological processes shape atmosphere and climate?**



Veritas
Credit: NASA



Credit: NASA



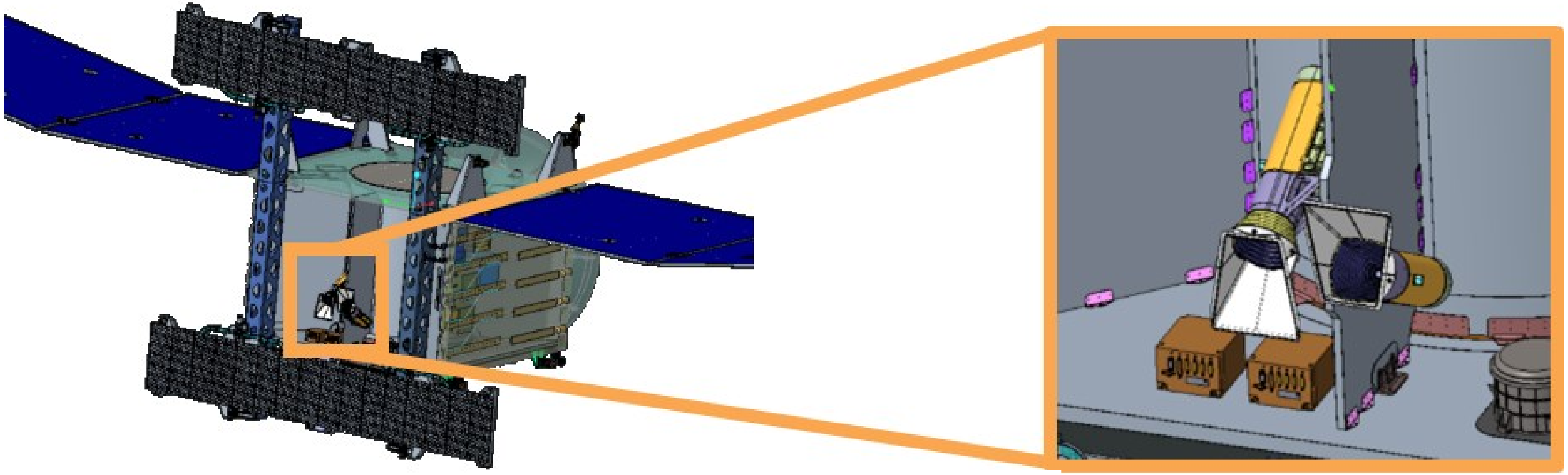
EnVision
Credit: ESA

Combining the surface mapping from VEM on VERITAS (NASA/JPL) and VenSpec-M on Envision (ESA) will allow to look for change and increase the coverage of the planet

EnVision launch 2031
Veritas launch shifted from 2027 → 2029 → 2031 → 2032

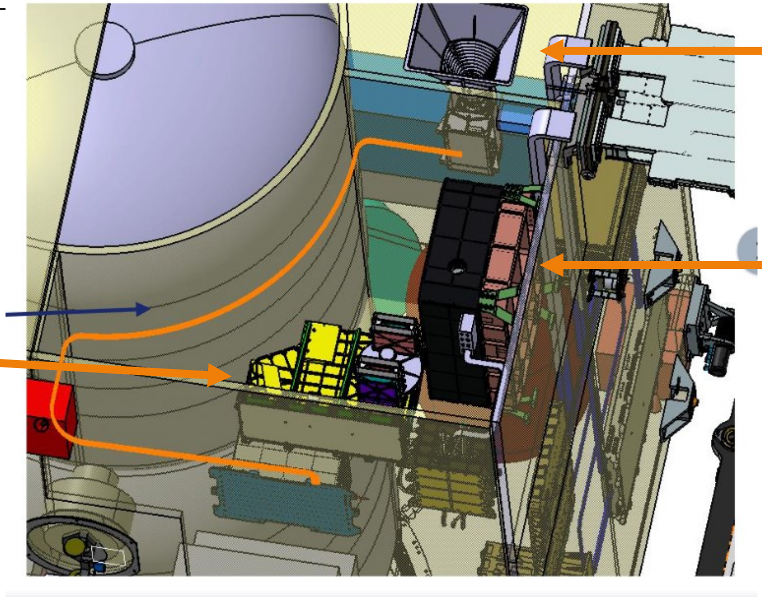
https://www.youtube.com/watch?v=W-UJ3yWpQns

Instrument accommodation



Veritas

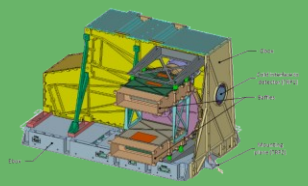
Credit: Lockeed Martin



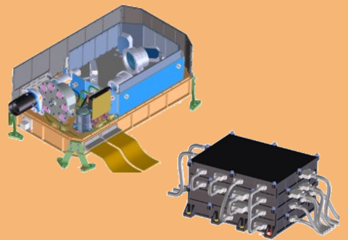
EnVision

Credit: Thales Alenia Space

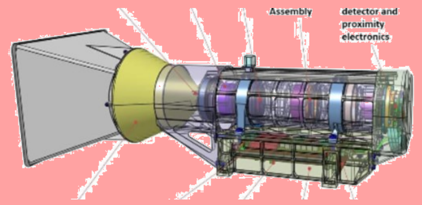
The VenSpec Suite - EnVision



VenSpec-U
Top clouds
Sulfur species, UV absorber



VenSpec-H
Cloud composition
Volcanic plumes
CO, OCS, HF, HCl, SO2, H2O



VenSpec-M
Thermal emissions
surface rock types

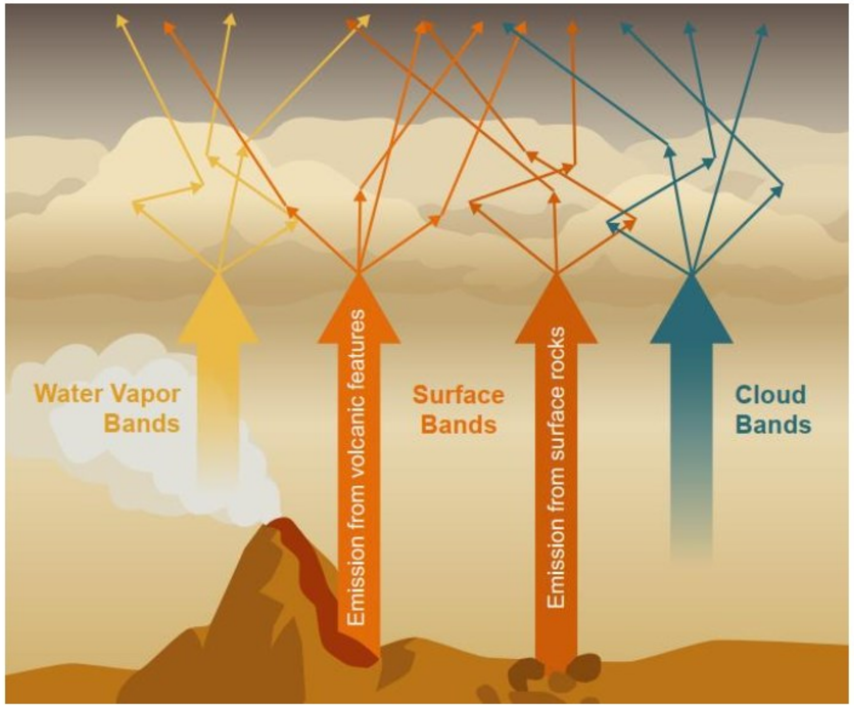
Three spectrometers with a **joint science & engineering team** for a collaborative geologic and atmopsheric research

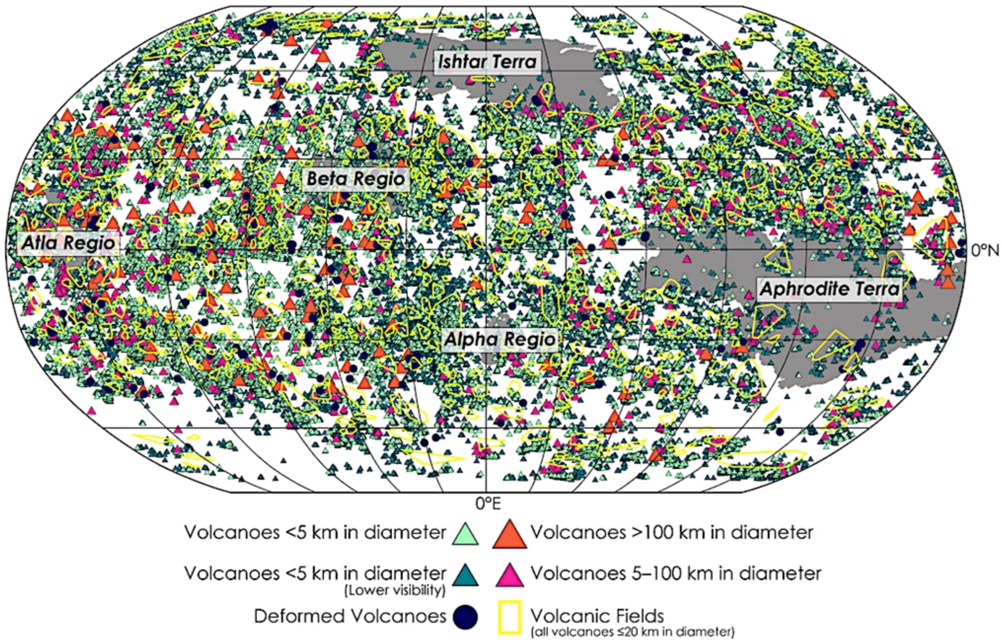

The Instrument
VEM/VenSpec-M

VEM/VESM – Instrument Science Goals

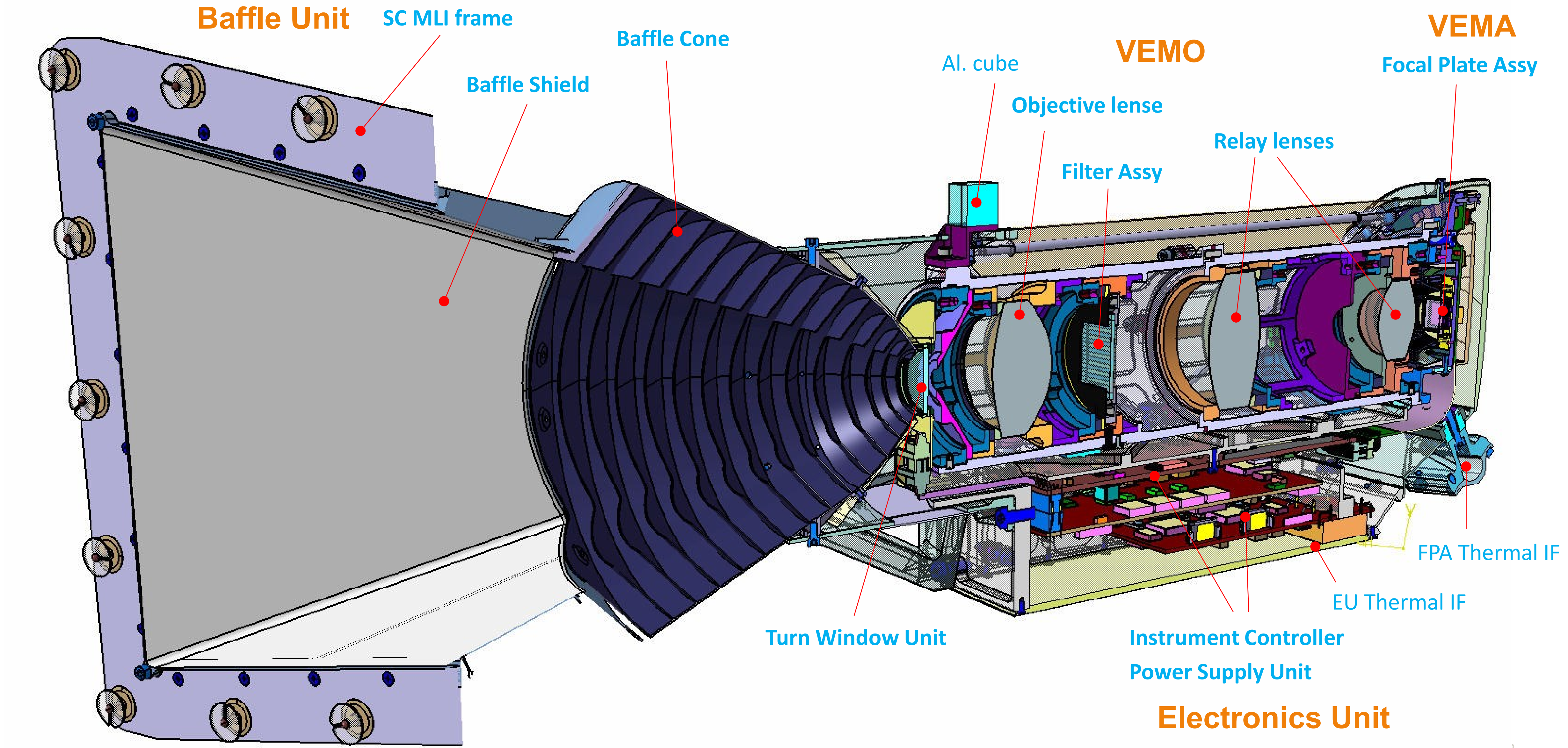
- Primary objective: global map of surface composition basalt vs granites with 70% coverage (Granite form in the presents of water)
- Second goal: volcanic activity (multiple looks on the same positions) expect 85000

- **Spatial resolution limited to 100 km** due to scattering in clouds

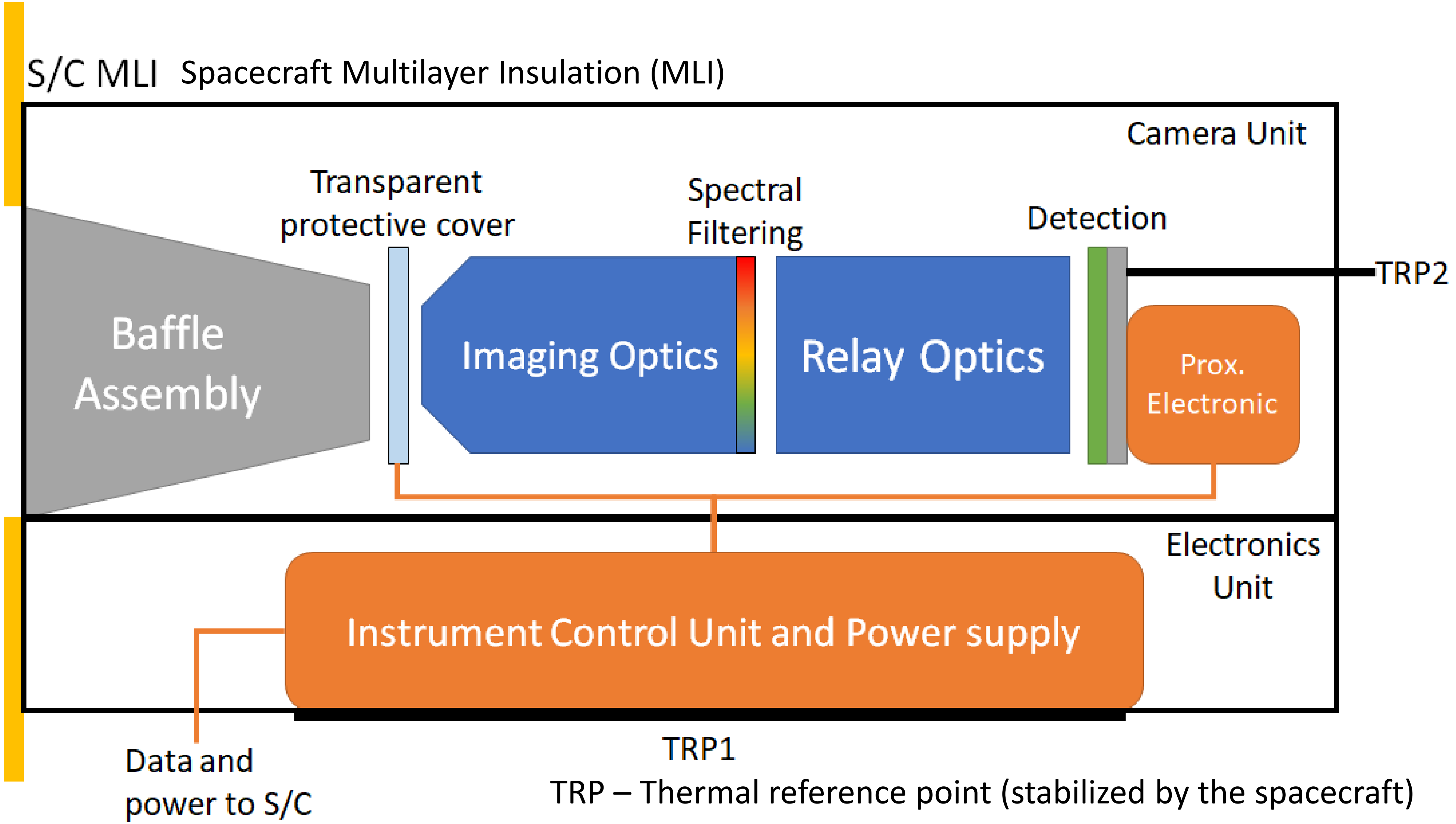




VEM/VESM Instrument

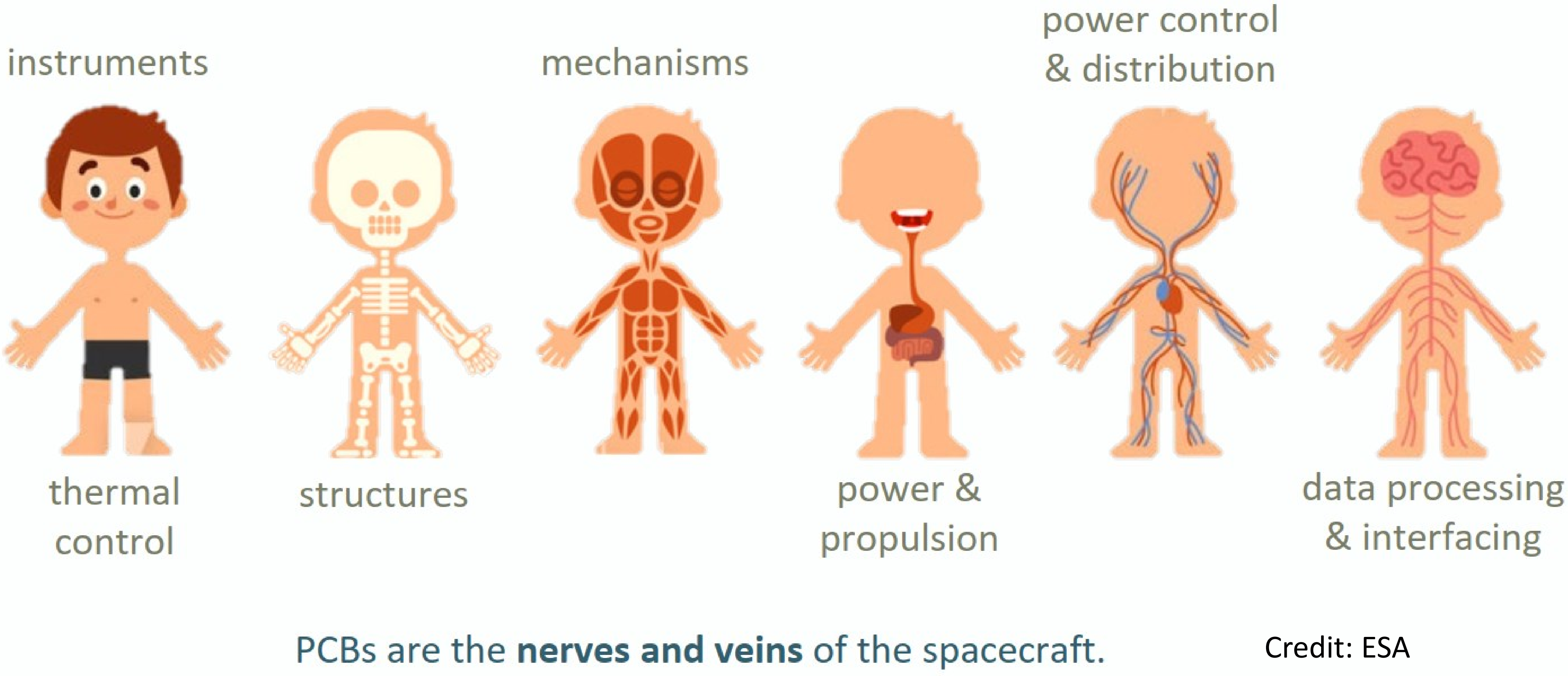


VEM/VESM Instrument - Functional block diagram



VEM/VESM Electronic

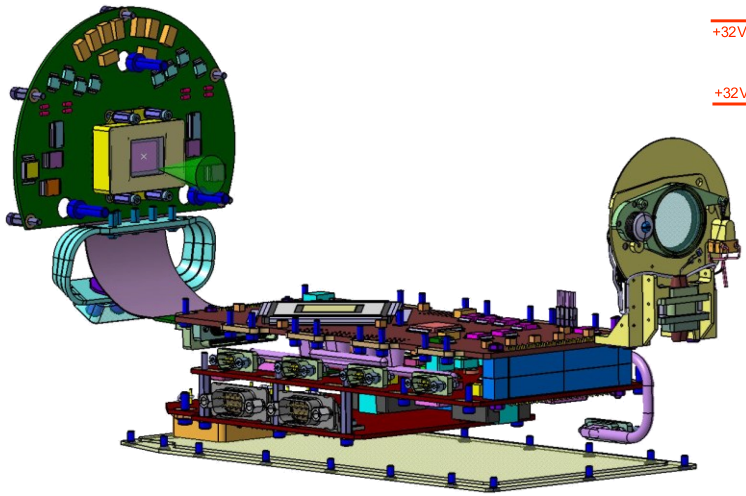
PCBs are the nerves and veins of the spacecraft

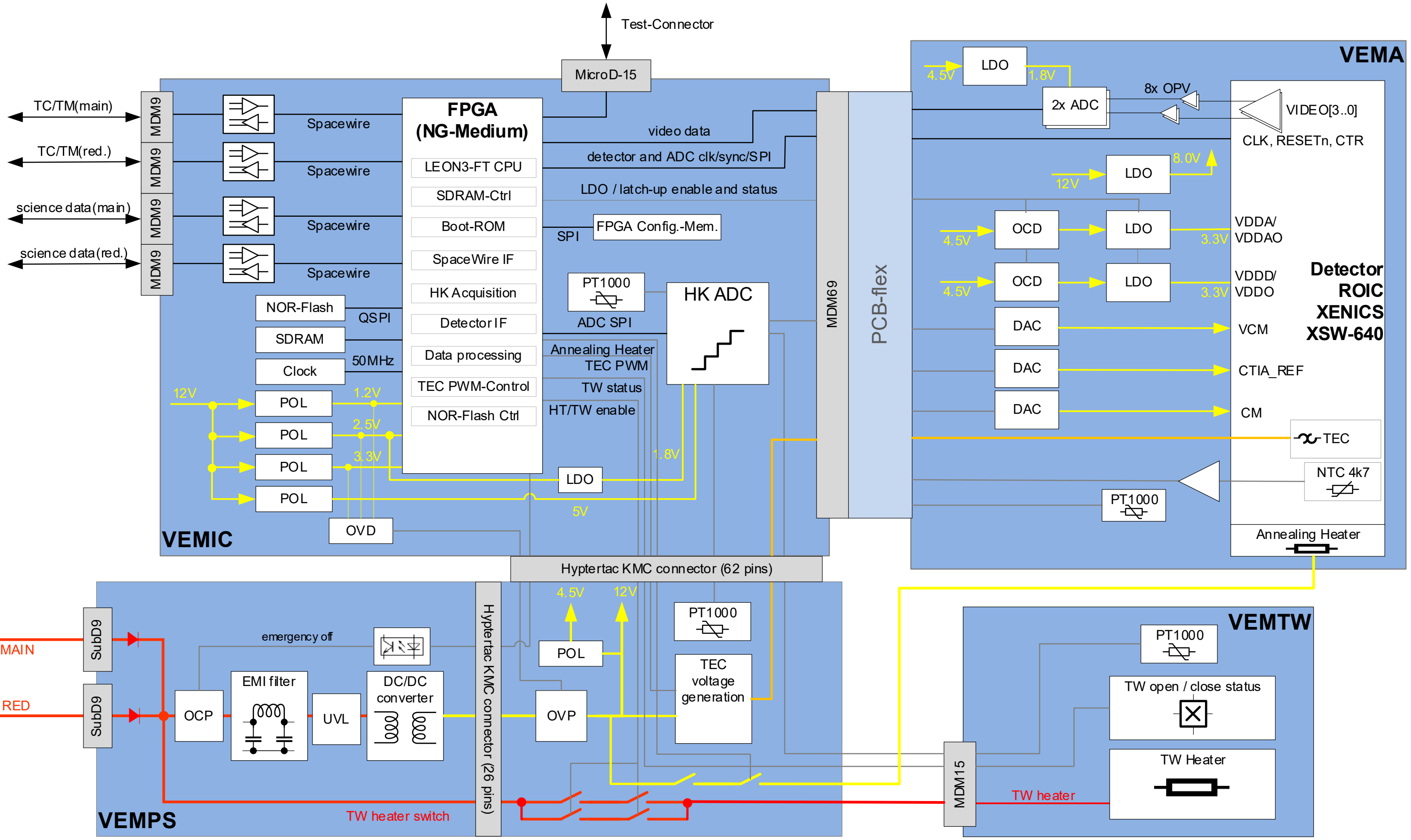


Credit: ESA

Electrical Architecture

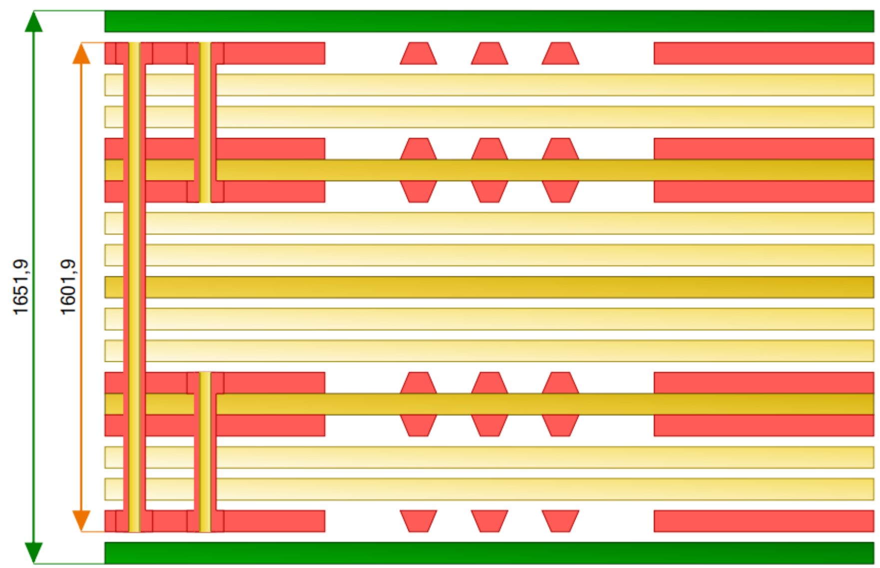
- Hardware comprises 4 sub-systems: power-supply (VEMPS), instrument controller (VEMIC), analogue electronics (VEMA), TWU electronics (VEMTW)
- Power supply and instrument controller are implemented as a stack of 3 PCBs
- The analogue electronics is connected via a flex PCB to the instrument controller.





VEM Electrical Functional Block Diagram (29st Jan 2025)

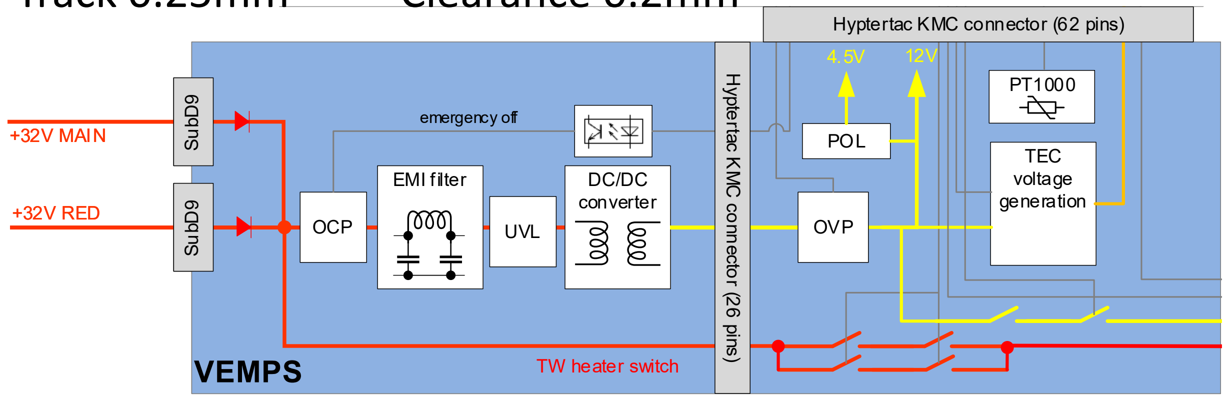
Power Supply Design - PCB

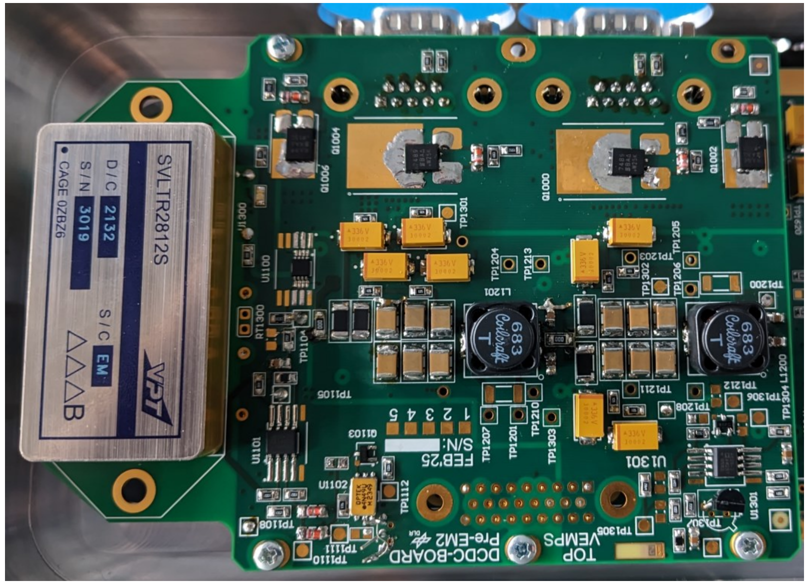


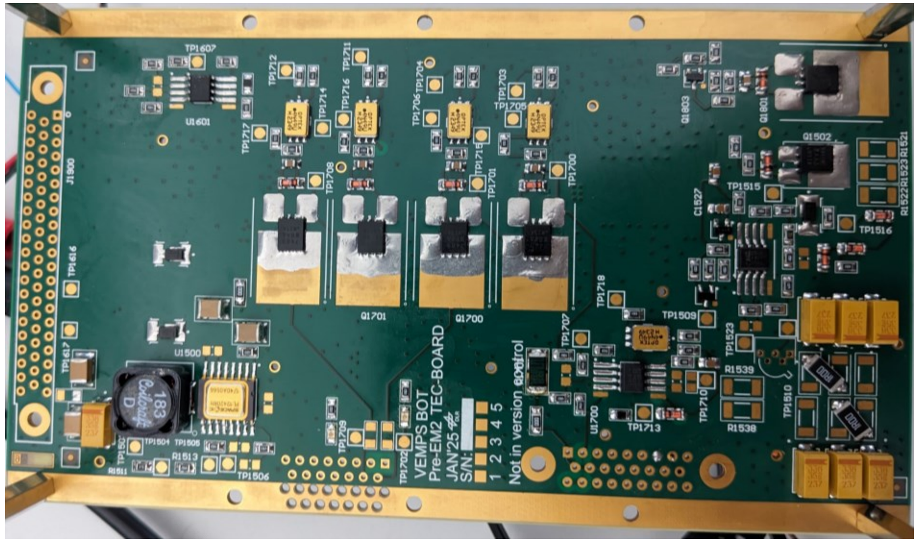
Lage	Lagenaufbau	Verarbeitete Dicke	εr	Herstellerbezeichnung	Type
		25,000	2,700	LDI Matt Grün	Lack
1		47,000		TZA HT	Folie
		57,125	3,900	R1650-M Typ 106	FR4
		57,125	3,900	R1650-M Typ 106	FR4
2		35,000			
		150,000	4,600	R1755-M	FR4
3		35,000			
		82,338	4,100	R1650-M Typ 1080	FR4
		82,338	4,100	R1650-M Typ 1080	FR4
		510,000	4,500	R1755-M	FR4
		82,338	4,100	R1650-M Typ 1080	FR4
		82,338	4,100	R1650-M Typ 1080	FR4
4		35,000			
		150,000	4,600	R1755-M	FR4
5		35,000			
		57,125	3,900	R1650-M Typ 106	FR4
		57,125	3,900	R1650-M Typ 106	FR4
6		47,000		TZA HT	Folie
		25,000	2,700	LDI Matt Grün	Lack

PTH 0.3/0.7mm　　Blind Vias 0.45/0.85mm

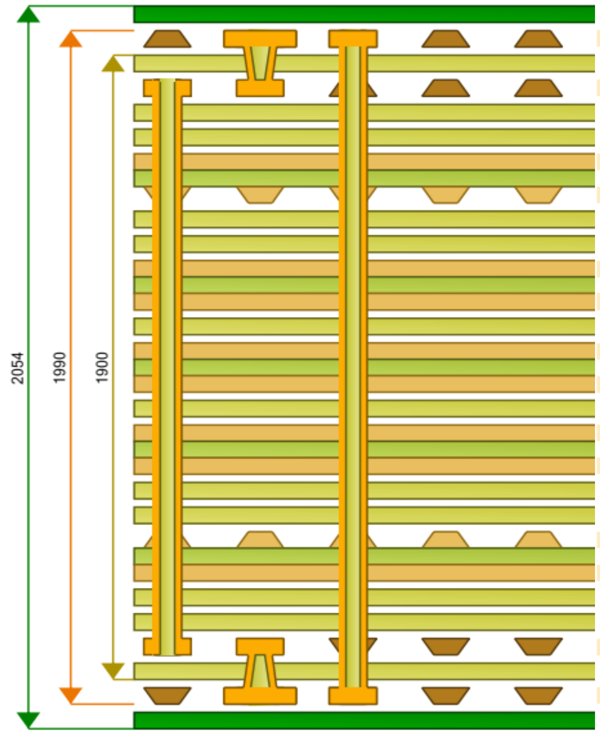
Track 0.25mm　　Clearance 0.2mm



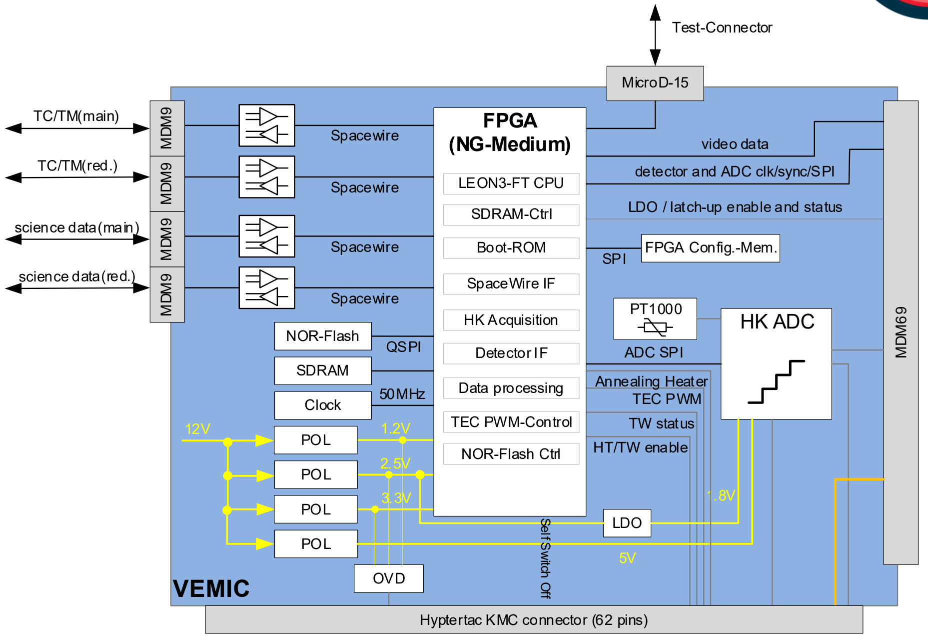


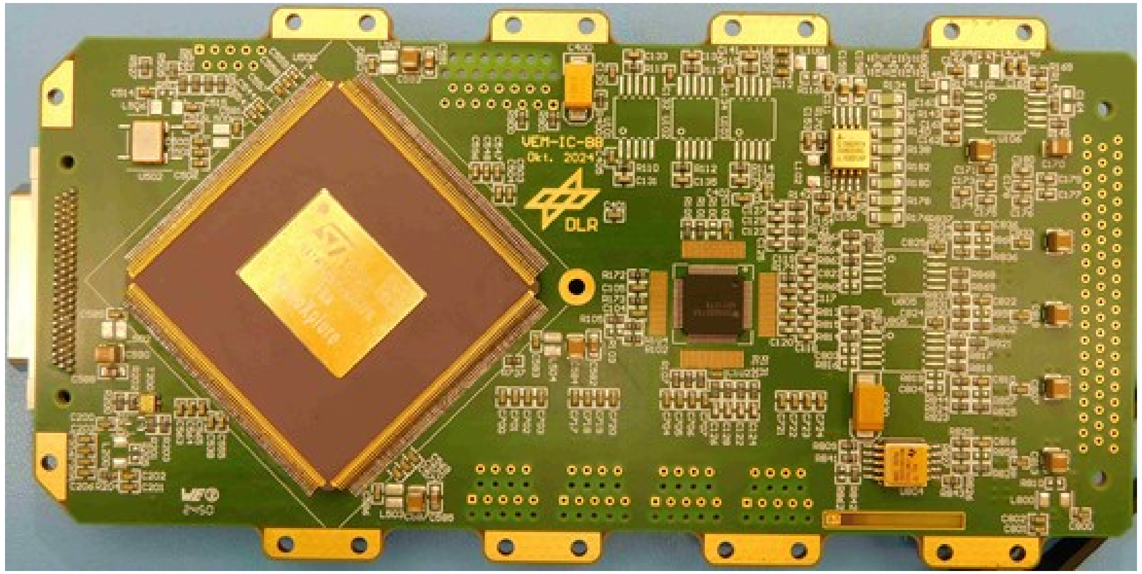


Instrument Controller Design - PCB



Layer	Stack up	Description	Supplier Description	Type	Base Thickness	Impedance ID
		Solder mask	Elpemer SD 2467 SM-DG	SM		
1		Cu-Foil	Kupferfolie	Foil	9.0	
		2116 HF	R1551W	PP	110.0	
2		Cu-Foil	Kupferfolie	Foil	9.0	1, 2
		2116 HF	R1551W	PP	110.0	
		2116 HF	R1551W	PP	110.0	
3					15.0	
		TG 150°	R1566W	Core	150.0	
4					15.0	3, 4
		2116 HF	R1551W	PP	110.0	
		2116 HF	R1551W	PP	110.0	
5					15.0	
		TG 150°	R1566W	Core	100.0	
6					15.0	
		1080 HF	R1551W	PP	73.0	
7					15.0	
		TG 150°	R1566W	Core	100.0	
8					15.0	
		1080 HF	R1551W	PP	73.0	
9					15.0	
		TG 150°	R1566W	Core	100.0	
10					15.0	
		2116 HF	R1551W	PP	110.0	
		2116 HF	R1551W	PP	110.0	
11					15.0	5, 6
		TG 150°	R1566W	Core	150.0	
12					15.0	
		2116 HF	R1551W	PP	110.0	
		2116 HF	R1551W	PP	110.0	
13		Cu-Foil	Kupferfolie	Foil	9.0	7, 8
		2116 HF	R1551W	PP	110.0	
14		Cu-Foil	Kupferfolie	Foil	9.0	
		Solder mask	Elpemer SD 2467 SM-DG	SM		





PTH 0.25/0.5mm PTH2 0.25/0.55mm µVia 0.15/0.3

Outer Layer Tack 0.25mm /Clearance 0.3mm

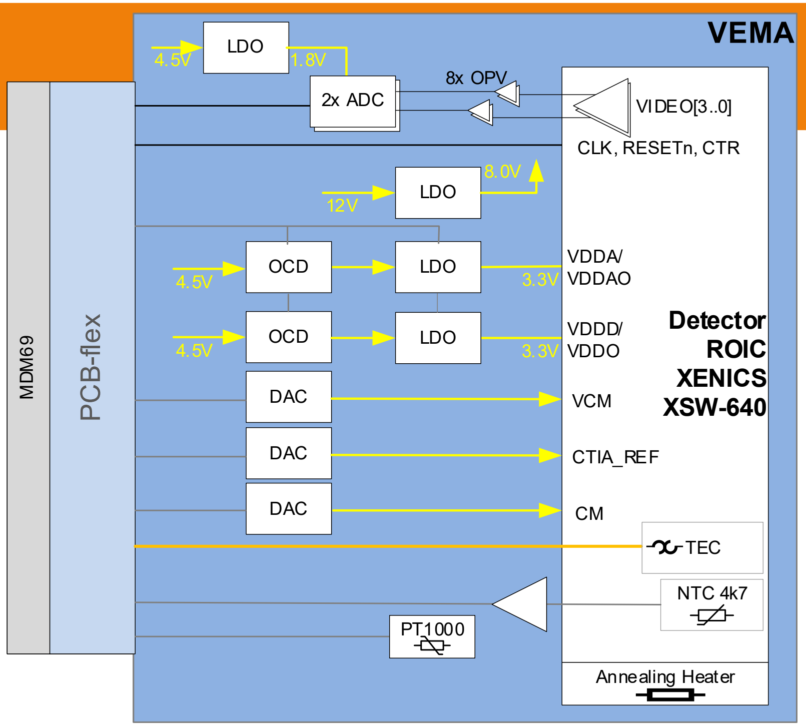
Inner Layer Track 0.1mm/Clearance 0.15mm

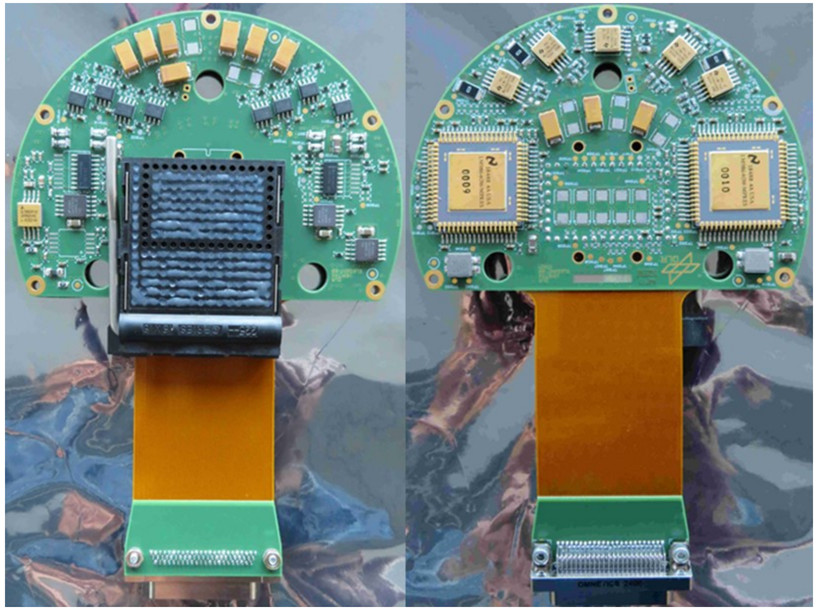
Detector Electronics Design - PCB

Layer	Stack up	Description	Type	Processed Thickness	εr	Copper Layer Type	Impedance ID
	1585,00 / 1521,00	Soldermask		32,000	3,500		
1		Cu-Foil		45,000		Signal	1, 2
		2116 TG150° HF	PP	105,000	4,600		
2		Cu-Foil		35,000		Plane	
		2116 TG150° HF	PP	110,000	4,600		
3				16,000		Signal	3, 4
		TG 150°	Core	100,000	4,600		
		3 x1080 TG 150° HF	PP	190,000	4,200		
4				16,000		Hatched	
		75µm Polyimide	Core	75,000	3,400		
5				16,000		Signal	5, 6
		2116 TG150° HF	PP	105,000	4,600		
6				16,000		Signal	
		75µm Polyimide	Core	75,000	3,400		
7				16,000		Hatched	
		3 x1080 TG 150° HF	PP	190,000	4,200		
		TG 150°	Core	100,000	4,600		
8				16,000		Signal	
		2116 TG150° HF	PP	110,000	4,600		
9		Cu-Foil		35,000		Plane	
		2116 TG150° HF	PP	105,000	4,600		
10		Cu-Foil		45,000		Signal	
		Soldermask		32,000	3,500		

Layer	Stack up	Description	Type	Processed Thickness	εr	Copper Layer Type	Impedance ID
	389,00	25µm Polyimide/25µm Adhesive	Coverlay	40,000	3,600		
4				16,000		Hatched	
		75µm Polyimide	Core	75,000	3,400		
5				16,000		Signal	1, 2
		25µm Adh / 50µm PI / 25µm Adh	Bondply	95,000	3,600		
6				16,000		Signal	
		75µm Polyimide	Core	75,000	3,400		
7				16,000		Hatched	
		25µm Polyimide/25µm Adhesive	Coverlay	40,000	3,600		

PTH 0.3/0.7mm PTH2 0.25/0.55mm µVia 0.1/0.35
Outer Layer Tack 0.2mm Clearance 0.25mm
Inner Layer Track 0.1mm Clearance 0.15mm





Main challenges during design phase

- Commercial detector failed radiation testing
  - Too many latch-ups during heavy ion testing
  - Need to change the detector → new qualification, change from digital to analog interface
- Hybrid DC/DC converter was seen as a major project risk from JPL
  - New hybrid DC/DC converter need to be chosen
  - Voltage changed from 5V -> 8.7V -> 12V
  - Different functionality (no EMI Filter, no OVP)
- FPGA was changed
  - Cost & power consumption
- Demanding and changing EMC requirements

PCB Assembly & Manufacturing

PCB Assembly & Manufacturing flow for the VEM/VESM Instrument

PCB Design (DLR)
ECSS-Q-ST-70-12C
↓
PCB Manufacturing (External)
ECSS-Q-ST-70-60C
↓
SMD (DLR + External)
IPC-J-STD-001 class 3 Space
↓
Commissioning + Rework (DLR)
ECSS qualified hand soldering
↓
Conf. Coating (DLR)
DLR qualified Process
↓
Acceptance (DLR)
Visual Inspection - IPC-A-610

- PCB design and manufacturing according to ECSS
  - Material: Arlon 35N or VENTEC VT901.
- SMD based on IPC Class 3S to have more flexible facility
- DLR internal hand soldering by ECSS certified operators
- Verification (Life and Microsections) on critical packages
- Acceptance according to ECSS and IPC IPC-A-610

ESA qualified PCB manufactures

Amphenol invotec

SYSTRONIC Groupe CIMULEC

elvia PRINTED CIRCUIT BOARDS

A&P Lithos Chateaubourg
Qualification in progress

(Ciretec discontinued due to fire)

ACB ADVANCED CIRCUIT BOARDS ATLANTEC CIRCUIT BOARDS

TESAT

CISTELAIER
Qualification in progress

Credit: ESA

IPC qualified PCB for space

- PCB manufactured with IPC class 3s is possible
  - For NASA missions is the baseline
  - For ESA missions it is an option with extra process control and approval by ESA
- In general:
  - ESA will need visit and approve the manufacturer
  - Process qualification & lot of paper work
  - Process control and approval is managed by ESA
  - Extra coupon with microsections (ESA defined)
- ESA mission classes give a guideline how much work its need to be done

Class type	I	II	III	IV	V
Mission Criteria and Marking					
Criticality to Agency strategy (Flagship mission, Internationnal cooperation, Impact on ESA strategic goals, and image)	Extremely high Criticality	High Criticality	Medium Criticality	Low Criticality	Educational purposes
Marking					
Mission Objectives (Directorate priority and purpose, e.g in orbit demonstration, educational)	Extremely high Priority	High Priority	Medium Priority	Low Priority	Educational purposes
Marking					
Cost (Cost at Completion, Including Phase E1)	>700 M€	200 - 700M€	50 - 200M€	1- 50M€	< 1M€
Marking					
Mission Lifetime (Nominal mission life duration)	> 10 years	5-10 years	2-5 years	2 years - 3 Months	< 3 Months
Marking					
Mission Complexity (Design interfaces unique payloads, New technology development)	High	High to Medium	Medium	Medium to Low	Low
Marking					

I - Critical safety issue (e.g. manned missions, Space Situational Awareness, operations center)

II - Performances should be met whatever it takes

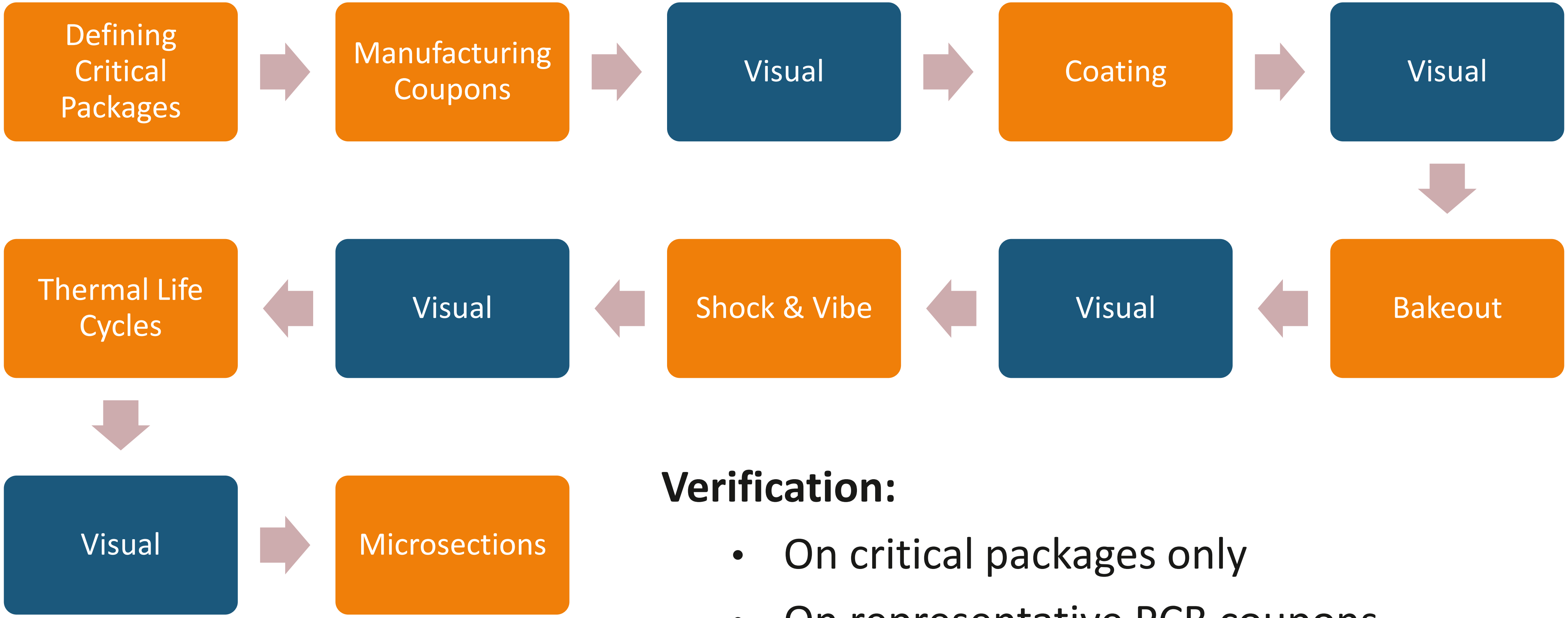
III - Finding the best compromise between risk and cost to deliver the mission

IV - Mission is designed according to a hard cost limit (affordability approach)

V - Almost full delegation to industry (e.g. newspace service contract, Public-Private Partnerships)

Credit: ESA

SMT Process and Qualification flow



Verification:

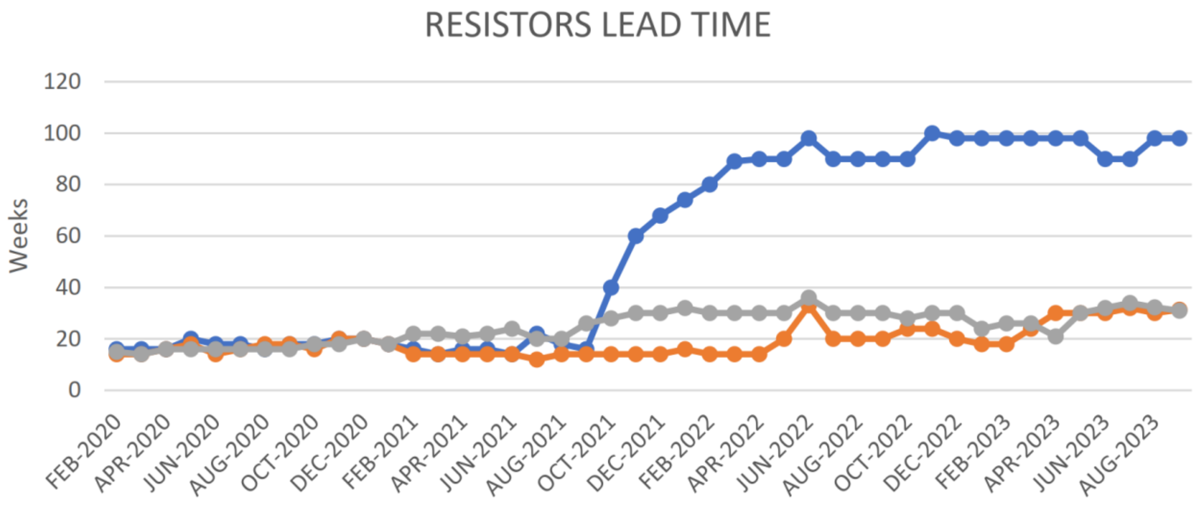
- On critical packages only
- On representative PCB coupons
- Mechanical Load
- Thermal Cycling
- Micro-sectioning

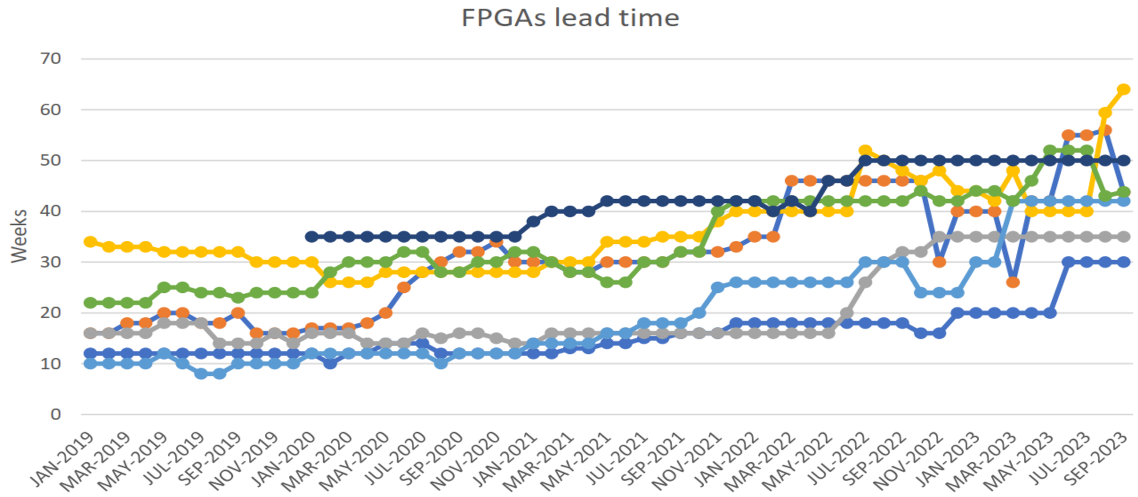
What are criticial packages?

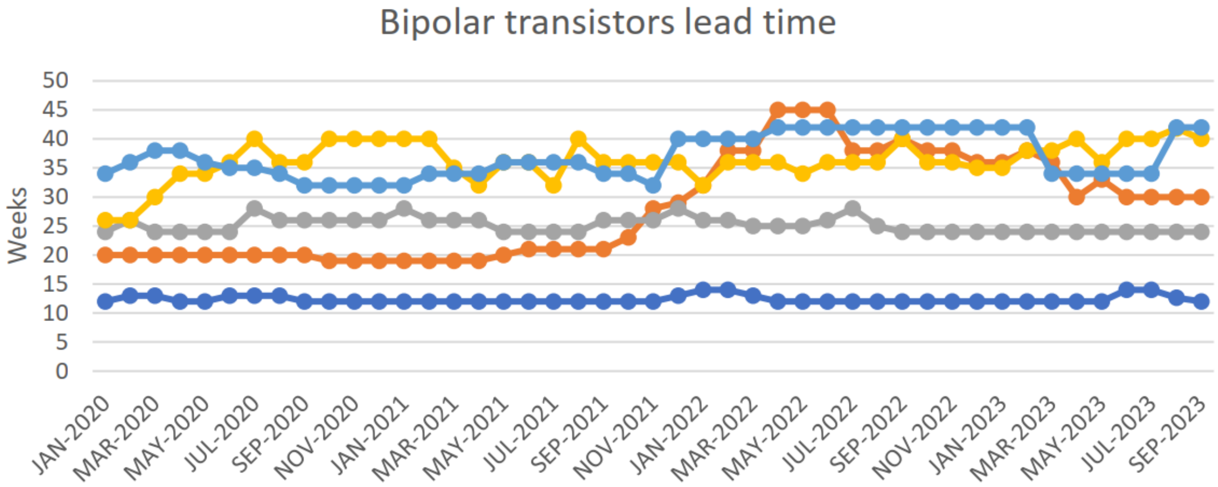
- Know history (heritage) and ESA and JPL lists
- Critical packages for VEM/VenSpec-M: 33 of 65
  - Eg: Flatpacks, Resistor/Capacitors <=0603 & >=2010, QFP, TSOP
- Coupons needs to be similar to the PCB the packages will be used on
  - Material, Manufacturer, Layerstack
- Multiple packages on the coupon 5-10 (on all micro sectioning)
- Whole qualification takes month 3-4 months with margin 6 months
  - Eg.: 420 thermal cycling alone: ~ 30days

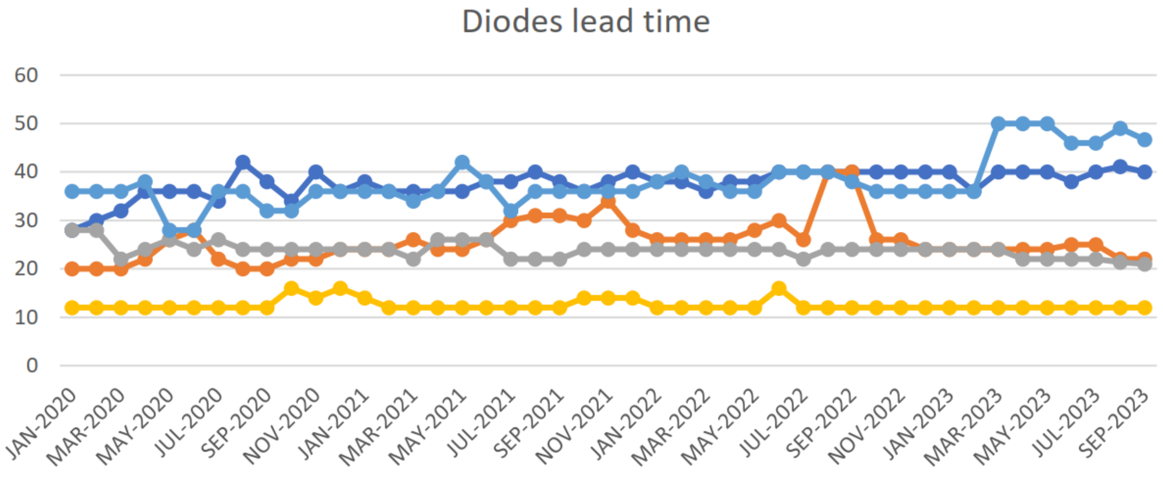
EEE Components

Space Component Lead Time





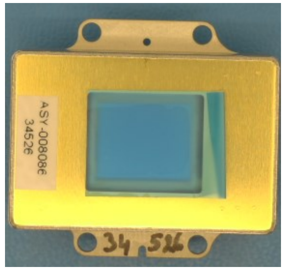


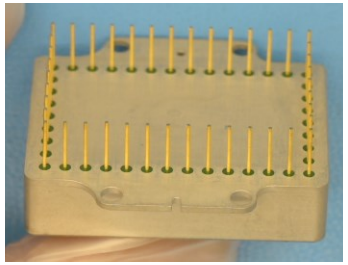


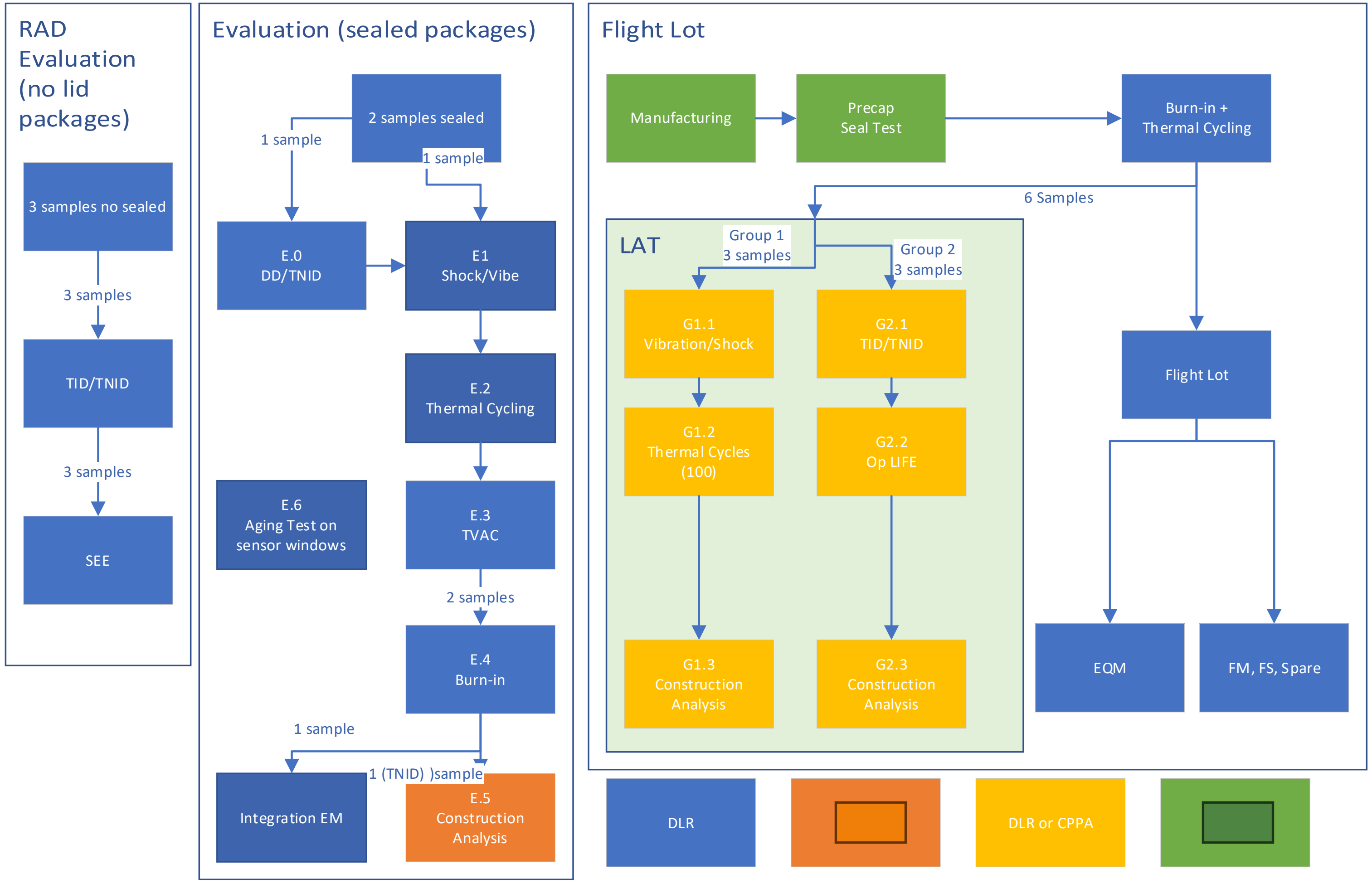
COTS Qualification for Space

- Only if there is no alternative or big numbers (new space, constellation)

- Evaluation campaign to demonstrated that your component works according to datasheet and your requirements (boundaries) in the mission environment
  - Duration a few months (limited availability for radiation facilities)







Questions?

Alexander.fitzner@dlr.de

Challenges what ever

- Environment challenges
  - Radiation
  - Vacuum
  - Low Outgassing/cleanliness (optical instruments)
  - Thermal (-40 to 80°C)
  - Mechanical loads (during launch)
- Component challenges
  - Cleanliness
  - Reliability (life time, failure propagation)
    - Reliability-, Worst Case-, Part Stress-Analysis, FMEA, Part Level FMEA
  - Leadtime & Cost
  - Less complex and older circuits (limited amount of different circuits)
    - Often discreet circuits ….
    - Radhard