PVA-FLEX-PIONEER

FINAL PRESENTATION - CONTRACT NUMBER N° 4000126081/18/NL/BJ/VA.

ESA-ESTEC NOVEMBER 27TH 2019

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Date: 27/11/2019
Ref: PVA-FLEX-TASB-PPT-0039
Template: 83230347-DOC-TAS-EN-008

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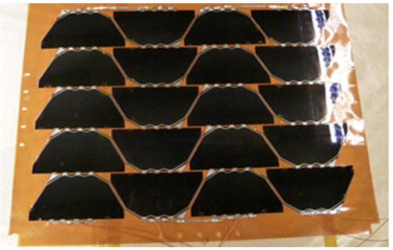
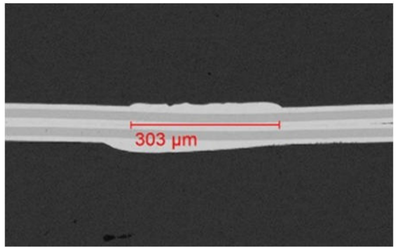
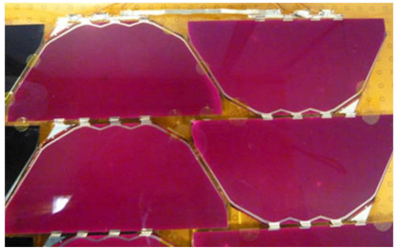
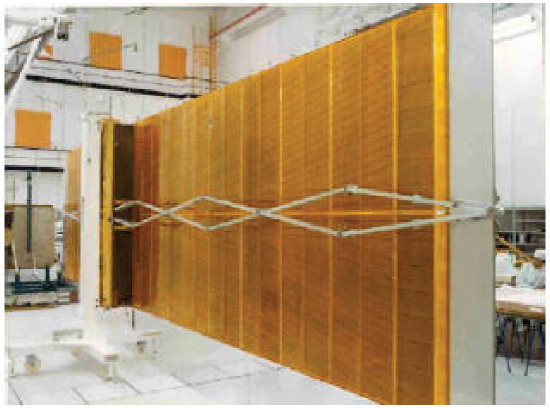






Historical Perspective



/// TAS most ancient heritage actually involves flexible photovoltaic “curtains” deployed with motorized pantographs: Implemented on SPOT satellites (‘86-’90-’93) then ERS (‘91-’95)- satellites.

/// Hubble satellite (‘90): flexible, retractable blankets

Figure 1: Spot-1 deployed flexible solar array

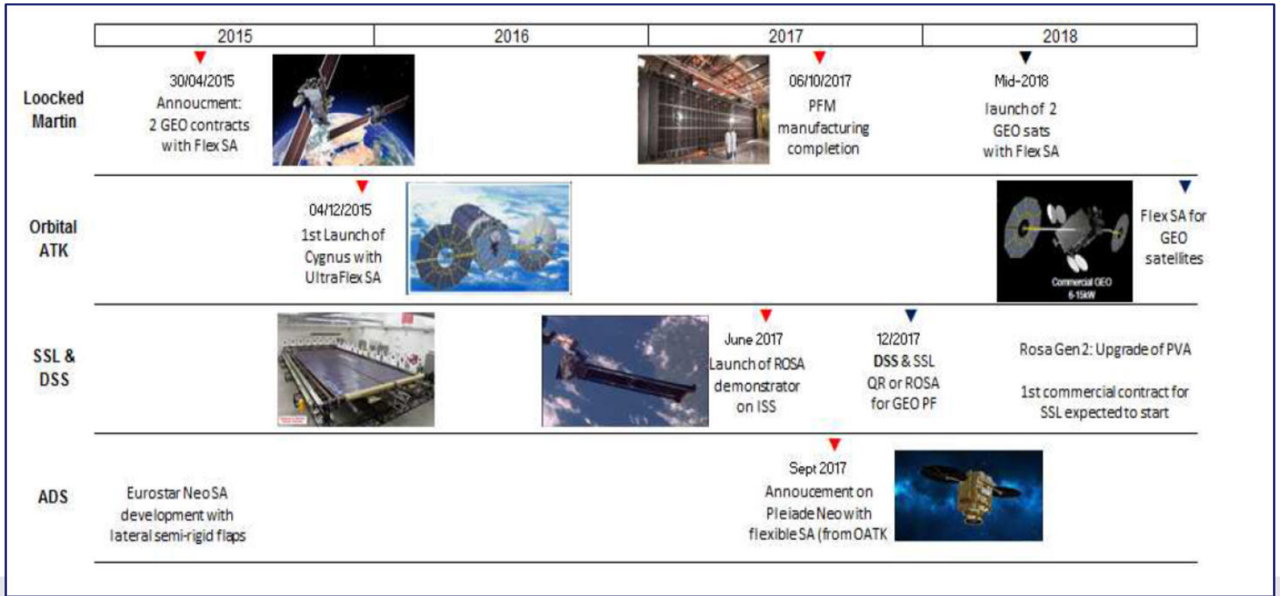
Flexible Solar arrays: market overview

/// Lockheed Martin:

/// Northrop Grumman (previously Orbital ATK)

/// SSL (Space Systems Loral) & DSS (Deployable Space Systems)

/// ADS



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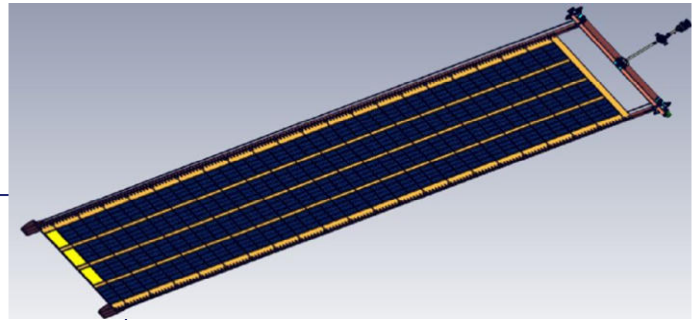
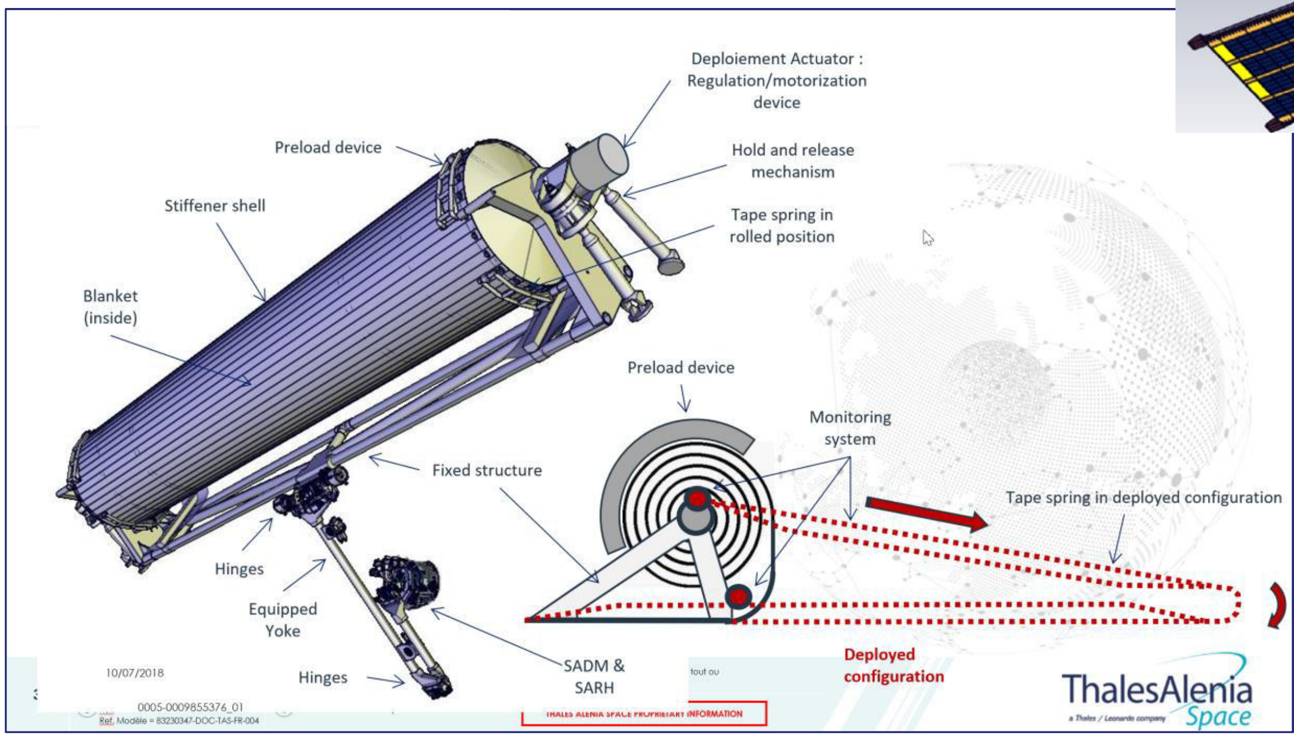
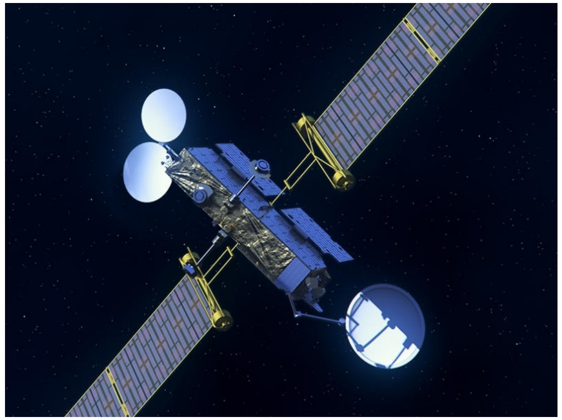
ThalesAlenia Space

Flexible Solar Array Design







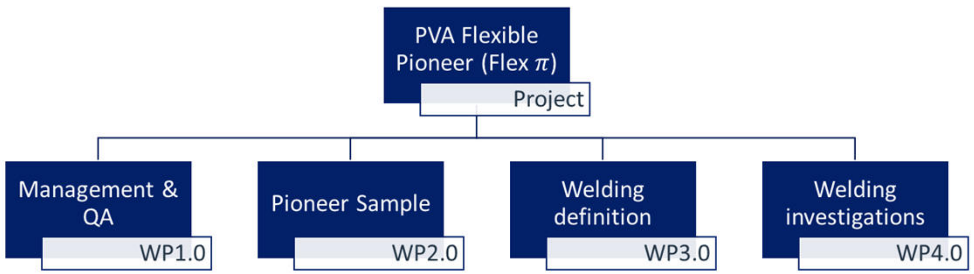
PVA-FLEX-Pioneer: Objectives

/// Deliver flexible PVA modules (Pioneers) to TAS-F to be integrated in their Solar Array EM (SCA from Azur & CESI)

/// Develop an alternate SCA interconnection process compatible with flexible requirements

- Planar or nearly planar
- Front-face
- Industrial

/// Introduce CESI SCA in TAS portfolio (welding parameters, interconnector design)



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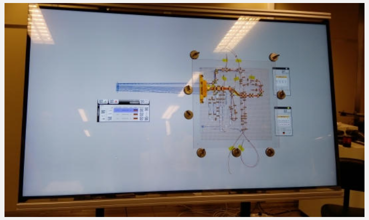
PVA Automated Line: current status

/// Status-Nov 2019: Preparing for qualification rigid-PVA

/// Further developments for Flexible: planned during 2020

Robots for SCA preparation:
Primer, Interco bending, Glue dispense

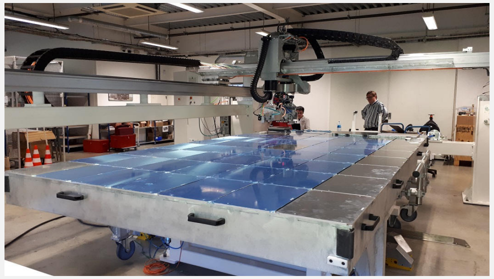
Laselec table: ***Harnessing preparation***

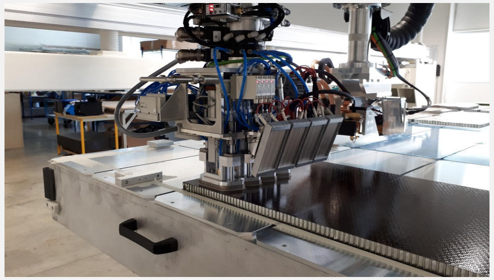


eATE: ***PVA testing***

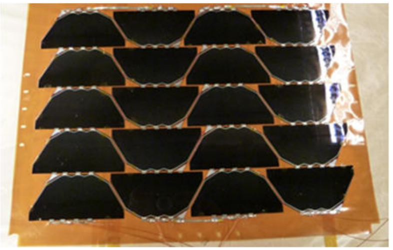
TVAC & APTC: ***Thermal cycling***

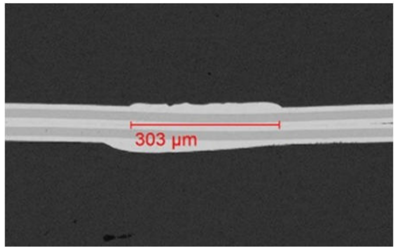
Main Gantry robot:
SCA placement + interco

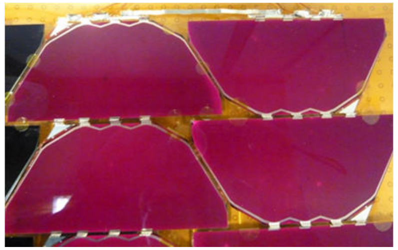




PVA-FLEX-PIONEER
FINAL PRESENTATION







Welding Requirements

1. The parallel gap welding technology shall be able to join interconnects made of **KOVAR plated silver** on both sides.
2. The parallel gap welding technology should be able to join parallel interconnects made of **INVAR plated with gold** on both sides.
3. The welds shall of a shear **strength of more than 100g**. This is tested with a pull test of two welded interconnects.
4. The resulting bond shall be able to resist ageing, induced by **thermal cycling** according to typical space mission requirements.
5. The automated welding shall be able to make at least **2 welds in 8 seconds**.
6. It shall be possible to fully automate the welding solution and this automation shall require minimal adaptations to the already in place **automated production line** of solar cells on rigid substrate at TAS-B.

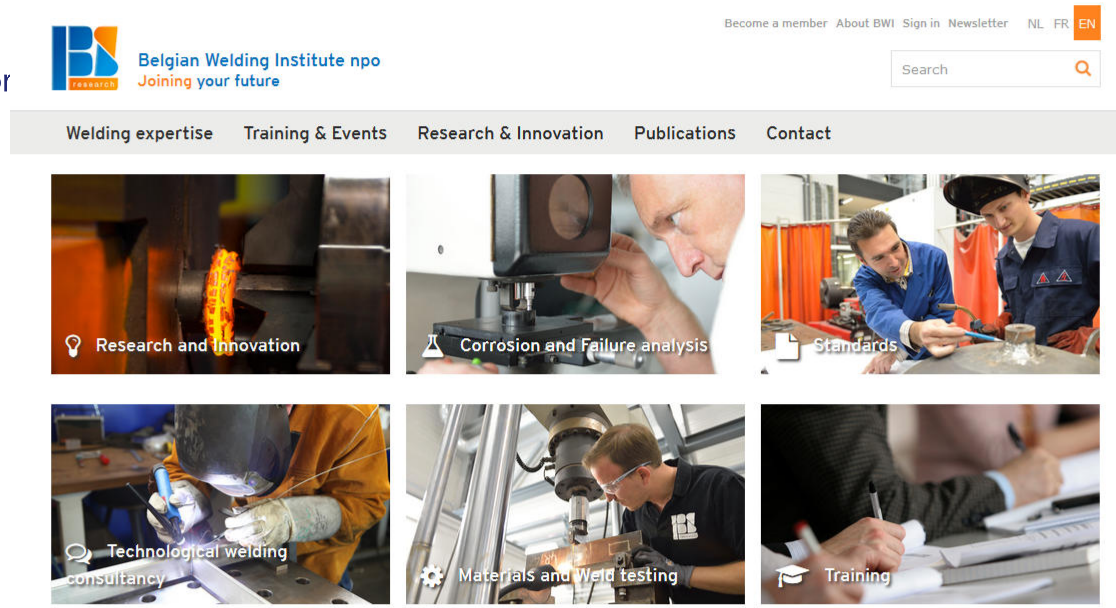
7. The interconnect-interconnect welding shall **not induce any damage** in the solar cell.
8. The interconnect-interconnect welding shall **not weaken the interconnector** itself
9. The welding process shall lead to **reproducible welds**.
10. A set of **in-process parameters** (and acceptable range respectively) shall be defined, with which the quality of the welds can be controlled.
11. The welding shall **not damage the PVA supporting substrate**.

Collaboration with Belgian Welding Institute

/// BWI: Expertise for different welding technlogies

/// Objectives:

- Comparison of different welding techniques for representative PVA interconnector materials
- Characterization of realized welding samples
  - Shear testing
  - Cross section
- Optimization of process parameters



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Welding technologies trade-off

/// Initial trade-off, with all available welding technologies, with possible application to join SCA interconnections, according to requirements (see previous slide)

- Resistance welding ☺
- Ultrasonic welding ☺
- Laser welding ☺

- Electron beam welding: ☹
  - Application in vacuum, high investment cost
- Friction stir welding ☹
  - Pin is to big(>1mm) to fit in the gap between two SCA's.
- Micro TIG welding ☹
  - Micro TIG electrodes are +- 1mm, so it will be very difficult to fit in the 1mm gap between SCA's

- Soldering: 😐
  - Consumables necessary (brazing paste)
  - Potentially less performing with respect to thermal cycling

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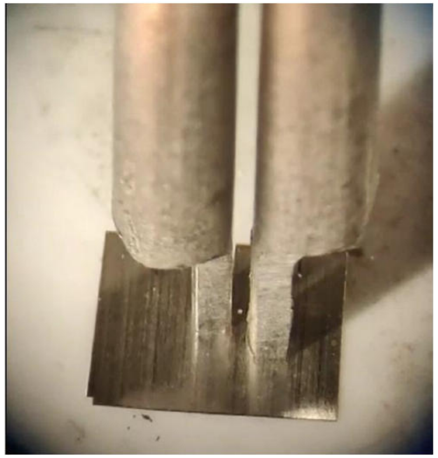
Resistance Welding

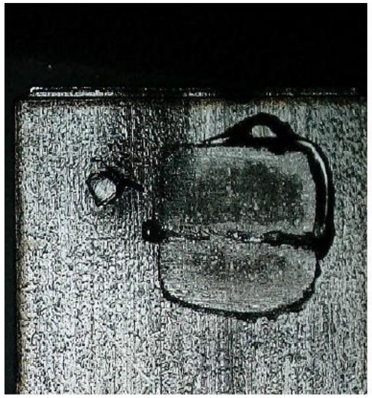
/// First tests with Mo and AgW electrodes succesfull

/// AgW electrodes gave better results than Mo

- Less melting on the surface of the interconnects
- Less sticking of the electrodes

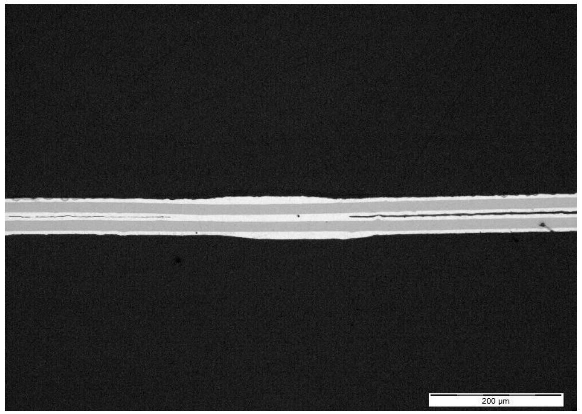
/// Electrode shape and parameters still to be optimised

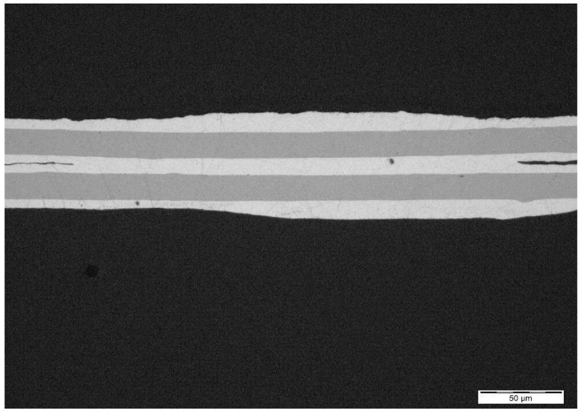




Imprint with Mo electrodes

Imprint with AgW electrodes





Ultrasonic welding

/// No previous experience with Ag-coated Kovar

/// Mechanical load is exerted on the parts to be welded. Under this load, the vibrations are transmitted to the interface between the material surfaces. The ultrasonic vibrations generate a heat between both materials, in order to plastify the materials and to generate a bond.

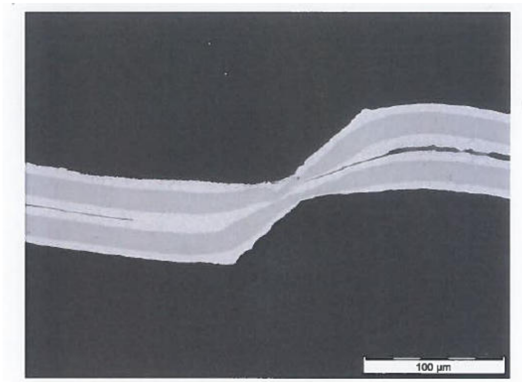
/// 1st test campaign using a 30 kHz Telsonic installation not successful :

- Test with different forces
- No plastification of the material / No joint formed

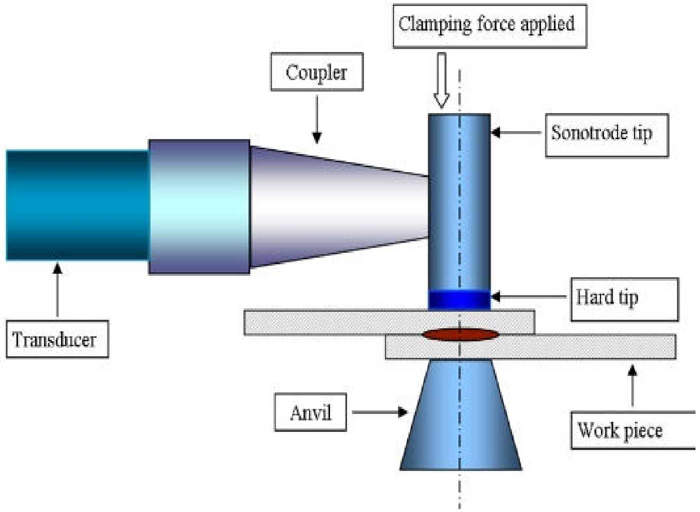
/// 2nd test campaign (20 kHz, 3kW power, max amplitude) :

- Joint was formed between the 2 Ag layers.
- Tensile testing: values bewteen 9 and 19N were obtained

/// Further Investigation necessary for parameter optimization



Ultrasonic welding of Ag-coated Kovar (×500)



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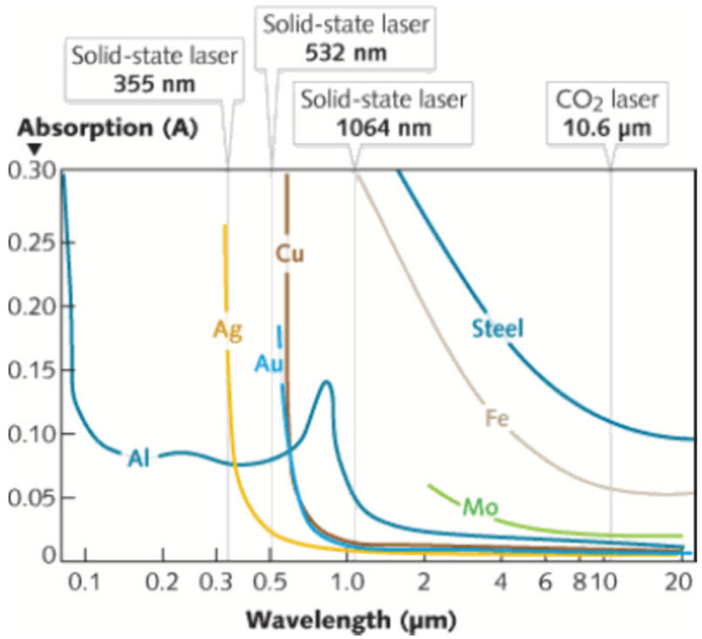
Laser Welding

/// Diode laser selected as most suitable laser technology

- Very low power needed (kovar must remain unaffected)
- Wavelength suitable for silver surface
- Trials done at Trumpf premises
- Tests performed with diode laser not successful :
  - Material is to thin
  - Complete melting could not be avoided

/// Further investigation needed to fully determine weldability



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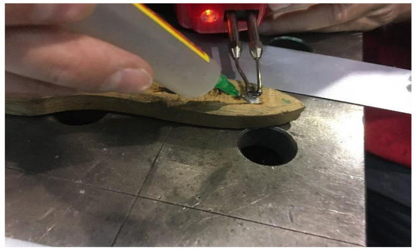
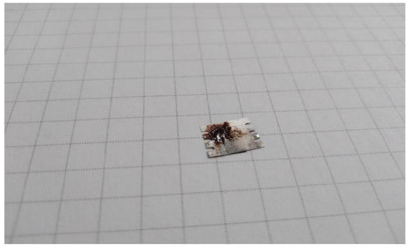
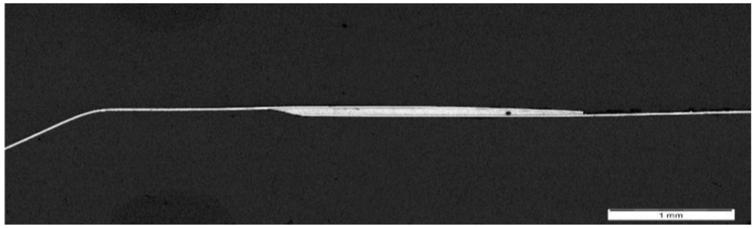
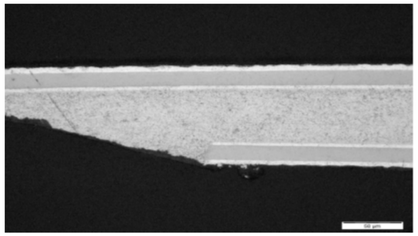
Soldering

/// First tests with Castolin 157(S-Sn96Ag4) solder paste successful

/// Tensile test results: between 43 and 7 N

/// No further tests were done, as welding was preferred over soldering.

Technology Comparison

Process	Advantages	Disadvantages
Resistance welding	• Easily automated • Low thermal impact on materials • Process is already known by Thales Alenia Space • No gas • High welding speed • Reliable process • Solid process	• Electrodes wear out • Support is necessary and must be very solid when parallel welding is used • Risk of Ag contamination on electrodes
Ultrasonic welding	• Low thermal impact • Easily automated • Can join dissimilar materials • Low heat input • Fast process • Clean process • Without melting	• Limited to thin and soft materials • Limited to lap joints • Only for selected range of materials, but possible for silver • The adherence of the coating must be very good, if not unsticking is possible because of the vibrations • Welding speeds • The horn is a consumable (needs inspection and replacement)
Laser welding	• Non-contact processing for joining in spaces with limited accessibility • No contact to workpiece • Good repeatability • Clean • Non-contact processing for joining in spaces with limited accessibility • Very high level of precision • Deep penetration is possible, shallow penetration also possible • Strong bonds (weld) • Low heat input	• Rather high investment cost (depending on power and laser type) • Sensitive for weld preparation (NO or limited (< 10% of plate thickness for butt welds) gap) • Metal parts need to be clean prior to welding (e.g. sulphur contamination can result in higher hot cracking sensitivity)

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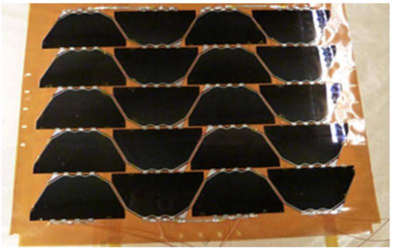

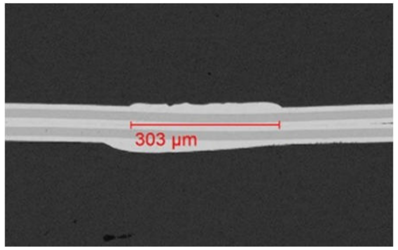

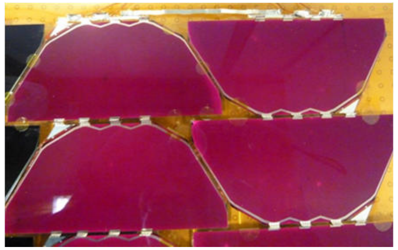

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Welding investigation: Tests made at Amada's factory

/// Objective: Tests the technology proposed by BWI.

/// Process tested: Parallel gap micro resistance spot welding

/// Material: Silver plated Kovar

/// Electrode material: Silver / Tungsten (35% / 65%)

/// Diameter of the electrodes: 1 mm

/// Gap between the electrodes: 0.3 mm

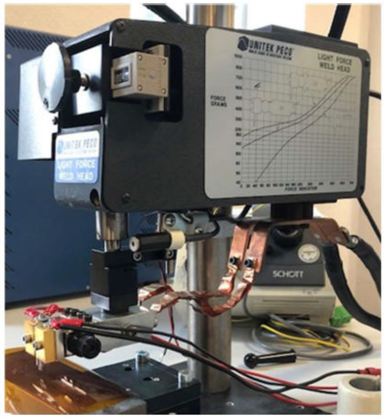
/// Applied force: 5 N

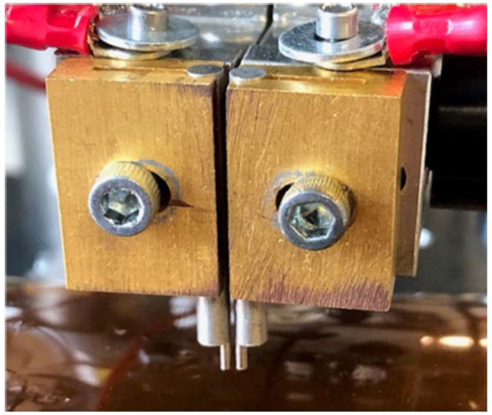
/// Number of pulse: 2

/// Voltage of the first pulse: 0.6 V

/// Voltage of the second pulse: Three tests were made with different parameters

- Test 1: 0.8 V
- Test 2: 0.85 V
- Test 3: 0.9 V





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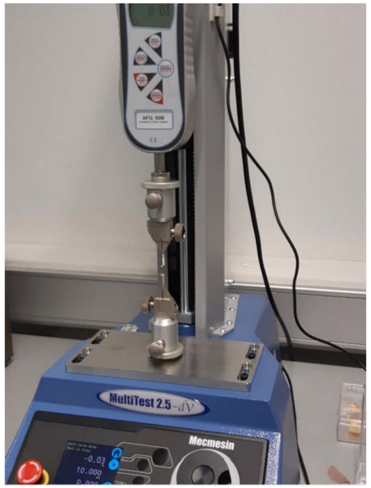
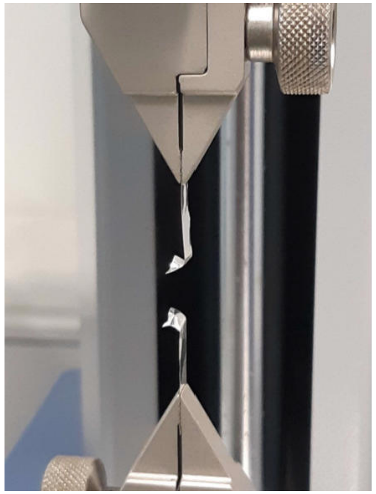
Welding investigation: Tests made at Amada's factory

/// After the determination of the tests set up, for each parameter 3 samples were made to realise micro sections and 30 welds were realised to be submitted to pull tests

/// Tests procedure: 2 strips of silver plated Kapton were placed one on top of the other onto a piece of Kapton sheet (200 HN). The welding were done every 3 cm on those strips.

/// The pictures hereunder show the pull test material





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Welding investigation: results (1)

/// Here is the table with the pull force results.

/// Specimen 1.X are the tests at 0.8 V

/// Specimen 2.X are the tests at 0.85 V

/// Specimen 3.X are the tests at 0.9 V

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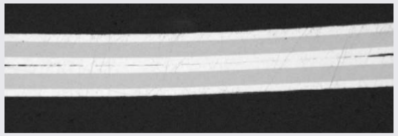
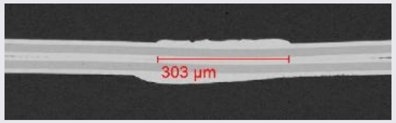
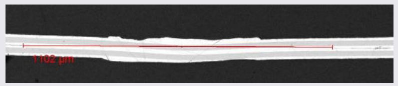
Welding investigation: results (2)

	Test at 0.8 V	Test at 0.85 V	Test at 0.9 V
Visual examination			
Micro section			

Welding investigation: results (3)

/// The prefered parameter was 0.85 V.

/// The pull forces were above our requirement of 1.5N (the minimum is above 3N).

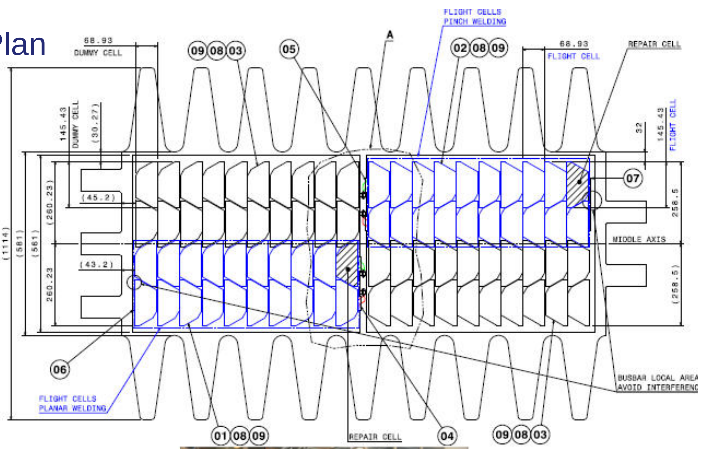
/// The visual aspect of the weld is smooth and the microsection show a good welding joint on at least 300 µm.

/// The results with 0.9 V were better but the visual of the welding point showed that it was a little bit overheated with bubbles in the silver under the electrodes so the risk of sticking are higher.

Welding Requirements – Follow-on activities

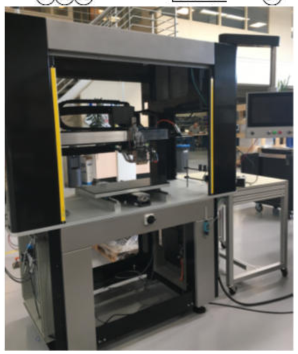
/// Selected parallel gap welding technologies specified at machine level

- 3 suppliers investigated out of Pioneer project for next step of Flexible Dev Plan
  - Specifications initially as a « Minimum Viable Product »



- Driving Requirements
  - SA Advanced mock-up module: 1.5m x 0.6m work area
  - Capability to weld in-gap: serial gap = 1.5 mm min.

- Selected solution: 1 « near » off-the-shelf solution proposed
  - Self-standing automated X-Y table with camera module & data collection module
  - Enabled for « feed-through » welding of larger modules at fixed maximum width
  - Enabled for connection to Belenos line (TBD if meaningful)
  - Closer to production requirements (but more expansive…)



- Development target
  - Further develop and tune machine with Pioneer process for **Pathfinder**
  - Capability to supply array-level validation models to validate in-plane i/c

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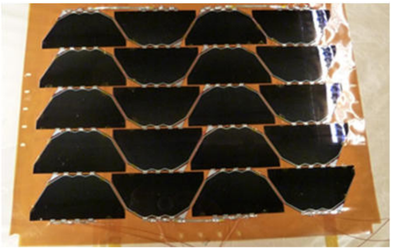
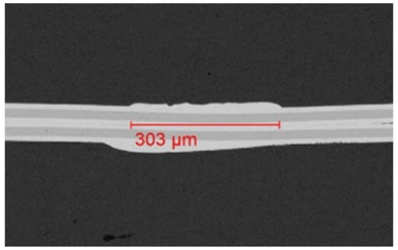
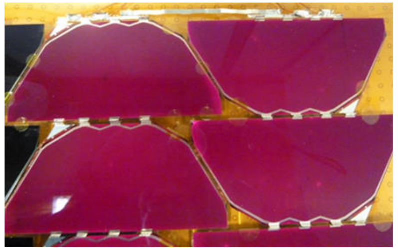






PVA-FLEX Pioneer Coupons: Objectives

/// First Flexible PVA demonstrators

/// Heritage processes from Rigid PVA

/// Tooling design for handling flexible substrates

/// 3 coupons, based on Azur & Cesi SCA

/// Test-plan

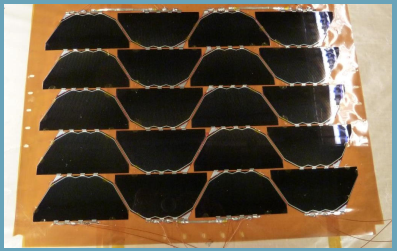
- Visual, ELM, Electrical
- Outside Pioneer project:
  - Roll-Unroll & Vibration
  - Thermal Cycling

Flex pioneer coupons

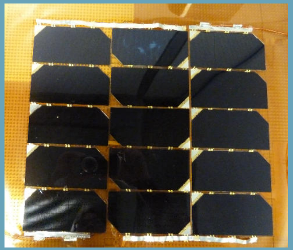
/// In the frame of this project 3 coupons were realised with 3 different layouts and SCA:

- One with Azur 3G30A SCA which will be called here « Azur Coupon »
- One with large (12 cm x 6 cm) CESI SCA Which will be called here « Large CESI coupon »
- One with flexible CESI SCA which will be called here « Flex CESI coupon »

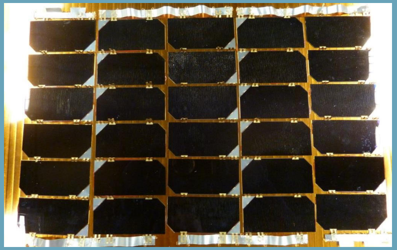
Azur Coupon



Large CESI Coupon



Flex CESI Coupon



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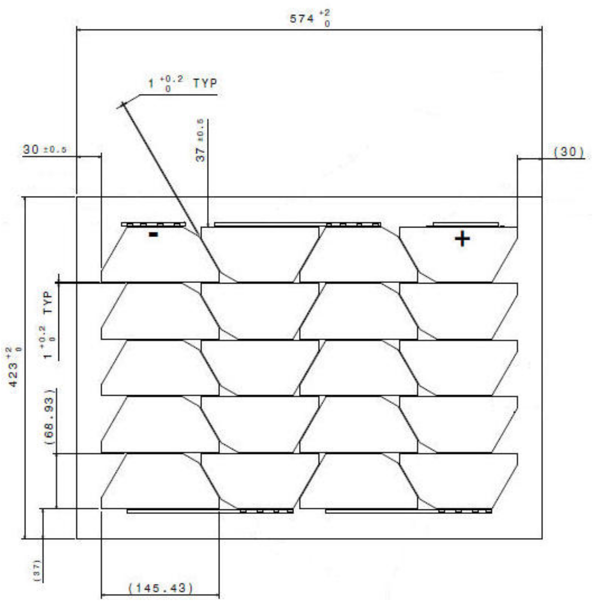
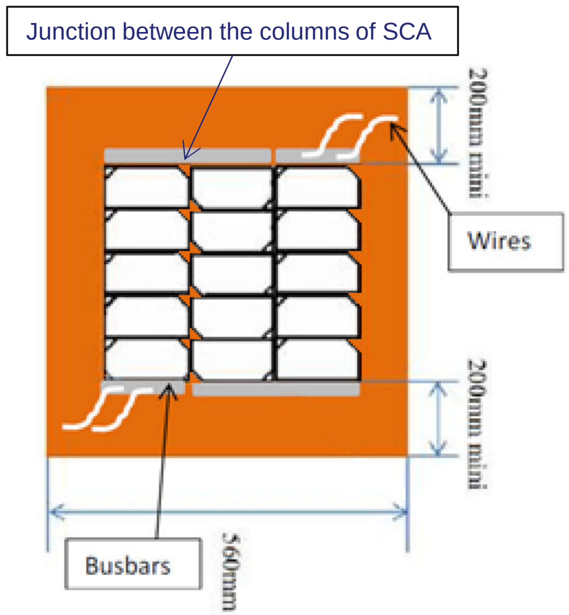
Flex pioneer coupons: Designs

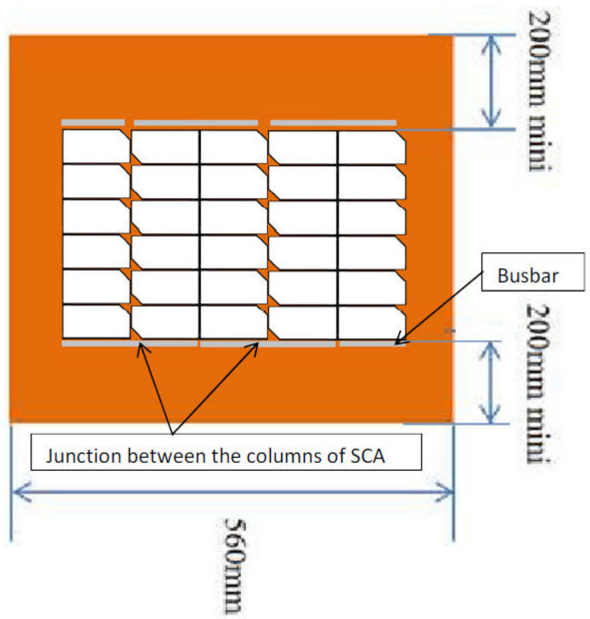
/// Here are the design of the 3 coupons



Azur Coupon



Large CESI Coupon



Flex CESI Coupon

Date: 27/11/2019
Ref: xxxxx
Template: 83230347-DOC-TAS-EN-008

Pioneer flex coupons: Part list

Item	Azure coupon	Large CESI Coupon	Flex CESI coupon
Substrate	Kapton 200 HN	Kapton 200 HN	Kapton 200 HN
SCA	SCA 3G30A 6in Hex CVG150	InGaP/InGaAs/Ge CTJ-LA-SCA-Dummy	InGaP/InGaAs/Ge CTJ-THIN-SCA-Flex-Dummy
Busbars (negative)	Busbars GEO / matched to i/co (negative)	Manually cut in a silver plated Kovar sheet	Manually cut in a silver plated Kovar sheet
Busbars (positive)	Busbars GEO / matched to i/co (positive)	Manually cut in a silver plated Kovar sheet	Manually cut in a silver plated Kovar sheet
Junction between rthe column of SCA	Manually cut in a silver plated Kovar sheet	Manually cut in a silver plated Kovar sheet	Manually cut in a silver plated Kovar sheet
Wires	ESCC 3901009 AWG24	ESCC 3901009 AWG20	ESCC 3901009 AWG24
Solder material	Sn / Ag solder wire	Sn / Ag solder wire	Sn / Ag solder wire
Primer	Primer Silicone G790	Primer Silicone G790	Primer Silicone G790
Adhesive 1	Kit resine RTV-S-691	Kit resine RTV-S-691	Kit resine RTV-S-691
Adhesive 2	CV1142	CV1142	CV1142

Pioneer flex coupons: Azur coupon manufacturing (1)

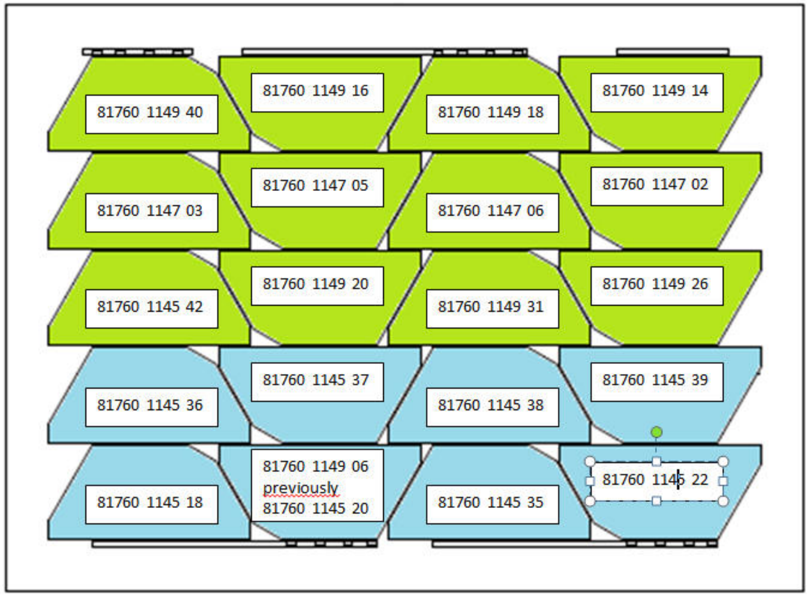
/// The coupons were manufactured using the process as the rigid ones (for example the praying hands welding)

/// The attached drawing represents the as build of the Azur Coupon.

/// The numbers in the SCA are the SCA ID used by Azur

/// The two lines in blue has been put in a first sequence and the three green lines afterwards

/// One SCA has been replaced (first line, second SCA from the left)

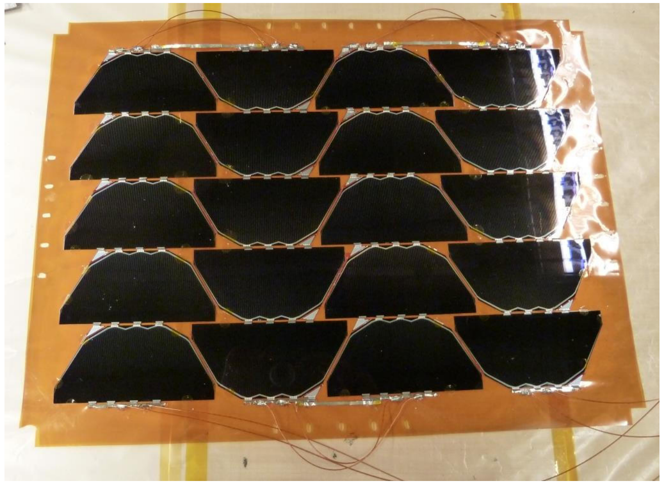


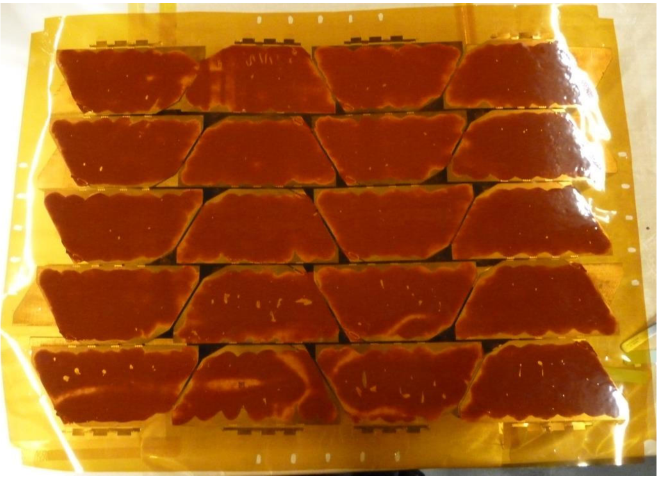
Date: 27/11/2019
Ref: xxxxx
Template: 83230347-DOC-TAS-EN-008

Pioneer flex coupons: Azur coupon manufacturing (2)

/// The following pictures show the front and back faces of Azur Coupon.

/// Several defect were identified like: coverglass and cell cracks, bubbles in the glue and lines with very low glue quantity.





Pioneer flex coupons: Azur coupon lessons learned

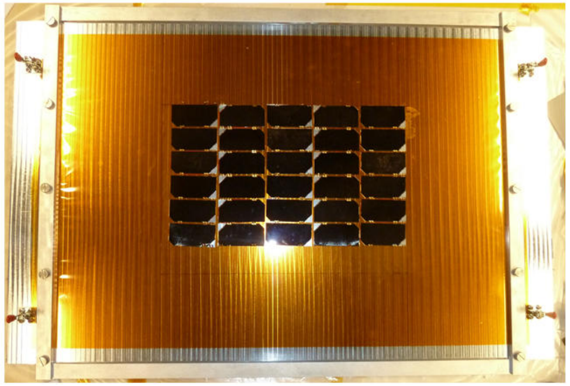
- /// The spacers that were used to realised this coupons were in ceramic and caused some coverglass and cell cracks.
- /// Creases in the Kapton sheet has caused the bubbles and the lines with very low glue quantity. The tool that was used to maintain the Kapton sheet was not fully adapted to the manufacturing
- /// The removal of a SCA in order to replace it was very difficult and we have deformed the Kapton a bit during this repair. In this configuration, on a complete flexible PVA a repair is impossible. The architecture and the processes used in the realisation of the flexible PVA has to be thought to ease the repairs.
- /// This coupon was very fragile some of the coverglass cracks might come from the manipulation that have been done to manufacture this coupons (not only from the spacers)

Pioneer flex coupons: CESI coupons manufacturing (Tools)

/// Dedicated tools were used for the manufacturing of those coupons

/// Those tools were made of a frame were the Kapton sheet is fixed and a plate to stretch the kapton sheet during the laydown of the SCA.

/// The following pictures showed those tools



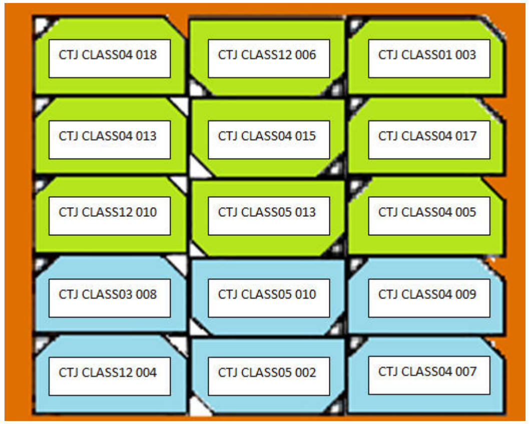
Date: 27/11/2019
Ref: xxxxx
Template: 83230347-DOC-TAS-EN-008

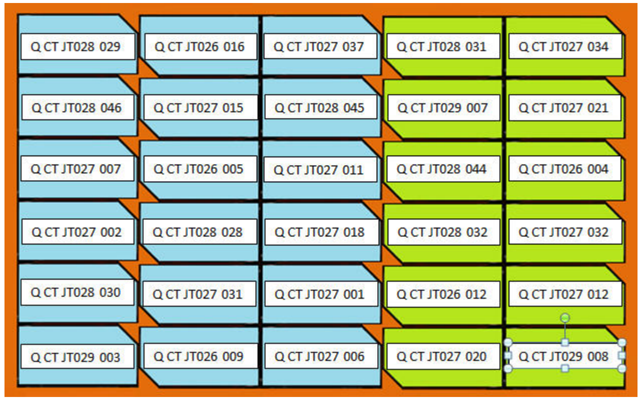
Pioneer flex coupons: CESI coupons manufacturing

/// The coupons were manufactured using the process as the rigid ones (for example the praying hands welding).

/// The attached drawing represents the as build of the CESI coupons. The numbers in the SCA are the SCA ID used by CESI

/// The blue SCA has been put in a first sequence and the green ones afterwards. Some of our pressure tools were not adapted to the small flex SCA so the manufacturing Philosophy has been adapted and instead of constructing it rows by rows it was constructed column by column.





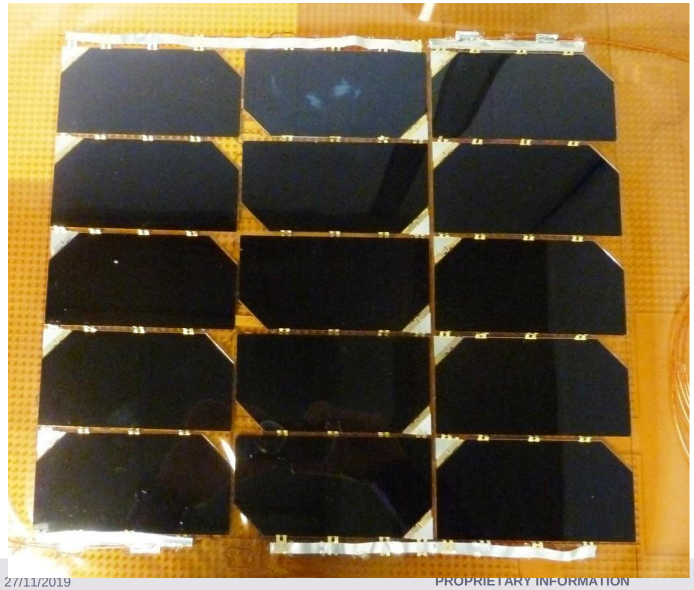
Date: 27/11/2019
Ref: xxxxx
Template: 83230347-DOC-TAS-EN-008

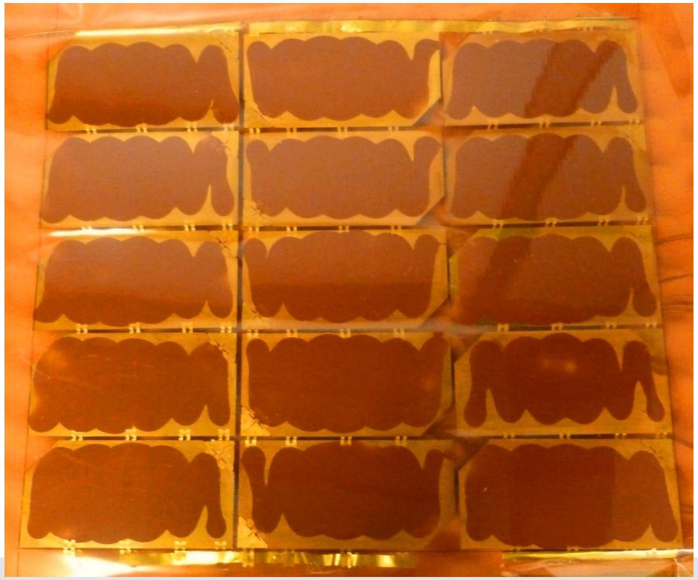
Pioneer flex coupons: Large CESI Coupon manufacturing

/// The following pictures show the front and back faces of the Large CESI coupons.

/// No real defect were identified during the manufacturing. ELM was not possible on that coupons. The SCA were mechanical ones and CESI confirmed us that their electrical performances could be null.

/// The tools developed for the laydown and the use of metallic spacers has greatly improved manufacturing of the CESI coupons.



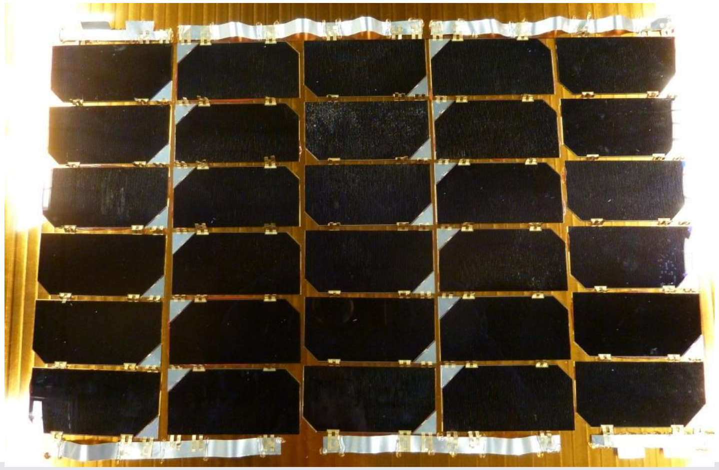


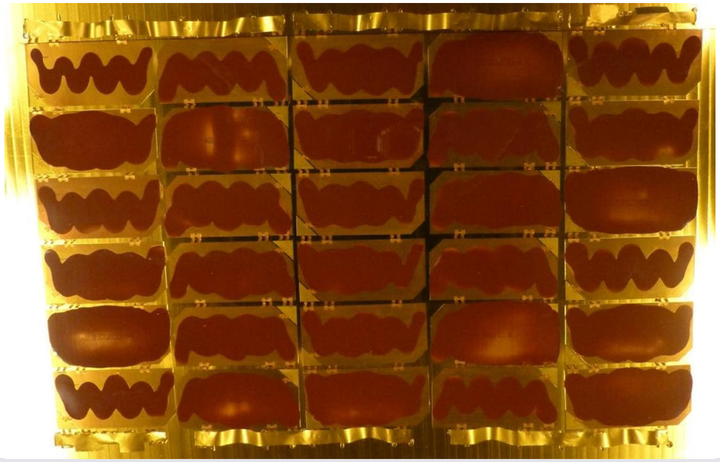
Pioneer flex coupons: Flex CESI Coupon manufacturing

/// The following pictures show the front and back faces of the Flex CESI coupon.

/// Several defect were identified like: coverglass and / or cell cracks, insufficient spreading of the glue, an alignment (horizontal and vertical) which was not perfect between the different SCA. ELM was not possible on that coupons. The SCA were mechanical ones and CESI confirmed us that their electrical performances could be null.

/// The tools developed for the laydown and the use of metallic spacers has greatly improved manufacturing of the CESI coupons.





Date: 27/11/2019
Ref: xxxxx
Template: 83230347-DOC-TAS-EN-008

Pioneer flex coupons: CESI coupons lessons learned

/// The tools developed for the lay down and the use of metallic spacers has greatly improved manufacturing of the CESI coupons.

/// Dedicated tools of the manufacturing of all the different type of coupons is a criteria of success. For the flex CESI SCA, a not adapted mass to push on the SCA after laydown lead to a bad spreading of the glue under some SCA and is also partly responsible of a bad alignment in the coupon

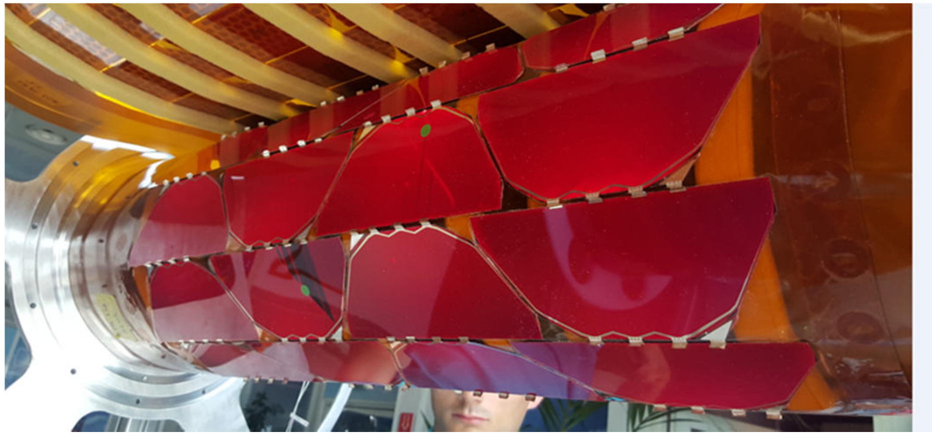
/// The welding of the CESI SCA has been very difficult because of a variability in the raw materials that has been delivered. Contacts has already been made with the CESI to seek ways of improvement.

Pioneer flex coupons: tests outside Pioneer project

/// Pioneer Integrated on Roll out solar array engineering model in TAS Cannes

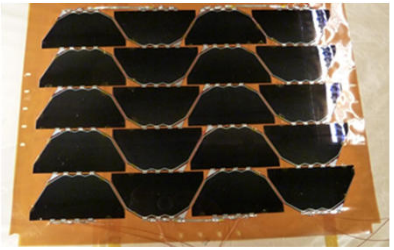
/// Roll in done, Vibration completed, ⇒ NO FAILURE

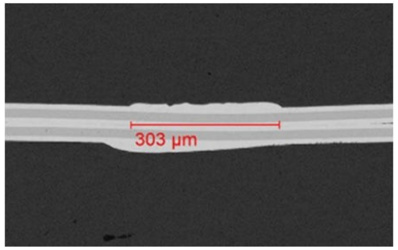
/// Thermal cycling [-175-156°C] (as passenger) ongoing (200 cycles completed)

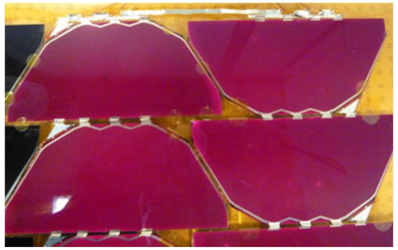


Date: 27/11/2019
Ref: PVA-FLEX-TASB-PPT-0039
Template: 83230347-DOC-TAS-EN-008

PVA-FLEX-PIONEER
FINAL PRESENTATION

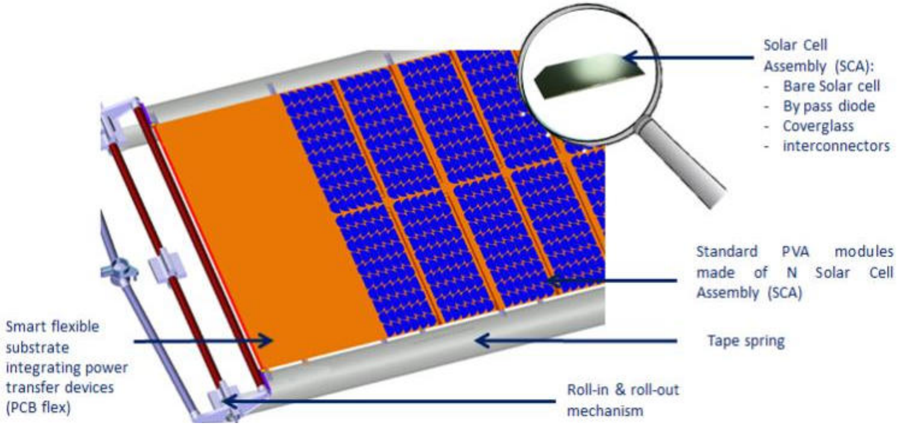






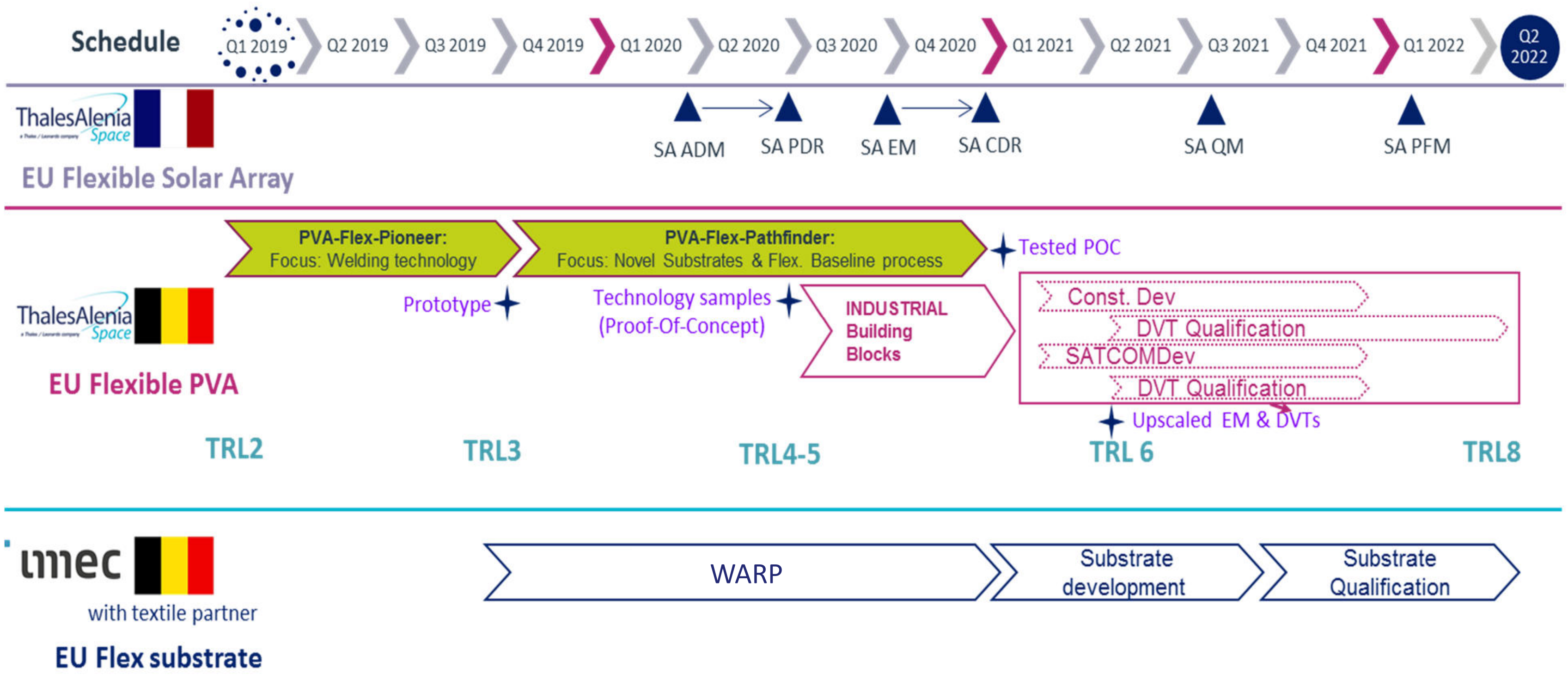
Flexible solar array: assembly building blocks

- Solarflex PVA
  - Equipped Blanket
    - Lateral stiffeners
    - Spacers
    - Blanket (substrate)
  - Power module
    - Diode board module
      - Diode
      - Board
    - SCA
      - Bare cell
      - Coverglass
      - Interconnector
    - Module harness
      - Busbars
      - Power carrier
      - Connectors
    - Transfer harness
      - Power carrier
      - Connectors



Date: 27/11/2019
Ref: PVA-FLEX-TASB-PPT-0039
Template: 83230347-DOC-TAS-EN-008

Development Plan: Flexible Solar Array - PVA & Substrate



Date: 27/11/2019
Ref: PVA-FLEX-TASB-PPT-0039
Template: 83230347-DOC-TAS-EN-008

WARP project (IMEC)

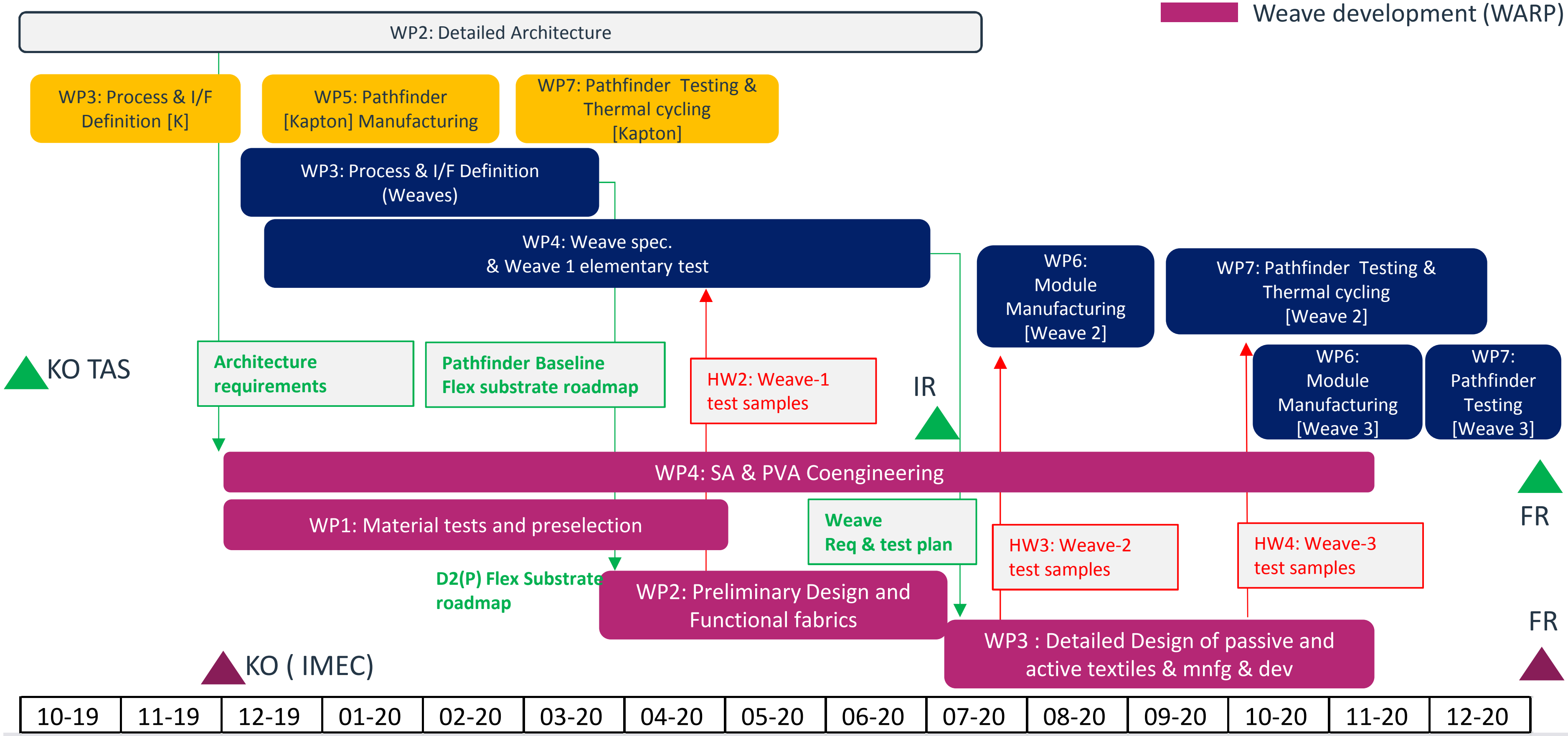
/// **W**OVEN F**A**B**R**IC FOR FLEXIBLE**P**HOTO**V**OLTAIC **A**RRAYFOR SPACE APPLICATIONS

/// **Goal: first demonstration of technical textiles substrate in rollable PVA structure with electrical and mechanical functions**

- Selection and validation of adapted **insulating filament** to meet space and functional requirements as well as compatibility with industrial weaving tools
- Develop a **weave design** integrating multiple mechanical functionalities and power carrier lines in the flexible PVA assembly
- Selection and **validation of adapted weave technology** and process parameters (through 3 iterative cycles)
- Co-engineering of the complete system and weave **integrated functionalities** for the next development stages
- Supply of **hardware samples** for the Pathfinder project for TAS-B

PVA-FLEX Pathfinder: Work Logic

PVA-flex-Kapton
PVA-Flex-Weave
Weave development (WARP)



Pathfinder & WARP development objectives

Development Objectives	Vehicles	Associated analysis/tests	Included in PVA-Flex-Pathfinder	Included in WARP-PVA see: [RD-3]
Verify that the base materials under trade-off for woven structure are compatible with space requirements	Test samples	Radiation + UV Vacuum Thermal range Mechanical characterization	x	x x x
Verify that the woven substrates are compatible with the mechanical requirements	Weave 1 Weave 2 Weave 3	Mechanical characterization		x
Prototype the assembly of SCA on the weave	Kapton Weave 1 Weave 2 Weave 3	Process inspections & quality control using elementary assembly tests.	x	
Prototype integration of mechanical interfaces **Prototype integration of electrical interfaces**	Kapton Weave 2 Weave 3	Process inspections & quality control.	x	
Realize an environmental test vehicle with lessons learnt from previous iterations	Pathfinder K Pathfinder W2 or W3	Thermal cycling & Vacuum	x	

PVA-FLEX-Pathfinder: Work package descriptions

/// See TASB-PRP-18141-1 for detailed descriptions

/// WP 01: Management and QA

- Objective: Execution of management and quality assurance tasks of the project

/// WP 02: Solar Array baseline architecture description

- Objective: Execution of management and quality assurance tasks of the project

Architecture

/// WP 03: Process and I/F definition

- Objective: Definition of the PVA-flex process baseline and interfaces

Technology development

/// WP 04: Weave specifications & Assembly testing

- Objective: Weave development support and elementary assembly tests.

/// WP 05: PVA-FLEX-Pathfinder-K

- Objective: Assembly of Pathfinder-K flexible PVA modules

Coupon **manufacturing** & testing

/// WP 06: PVA-FLEX-Pathfinder-W

- Objective: Assembly of Pathfinder-W flexible PVA modules

/// WP 07: PVA-FLEX-Pathfinder-Testing

- Objective: PVA-FLEX-Pathfinder-Testing

PVA-FLEX-Pathfinder coupons

Hardware Item Identifier	Description
HW1	Pathfinder-K (based on kapton solution)
HW2	Pathfinder-W2 based on weave-2 flexible substrate
HW3	Pathfinder-W3 based on weave-3 flexible substrate

/// HW-1:

- Baseline Pathfinder-coupon, using **kapton substrate**
- Implementation of parallel welding technology
- Automized front-side processes (as much as possible)

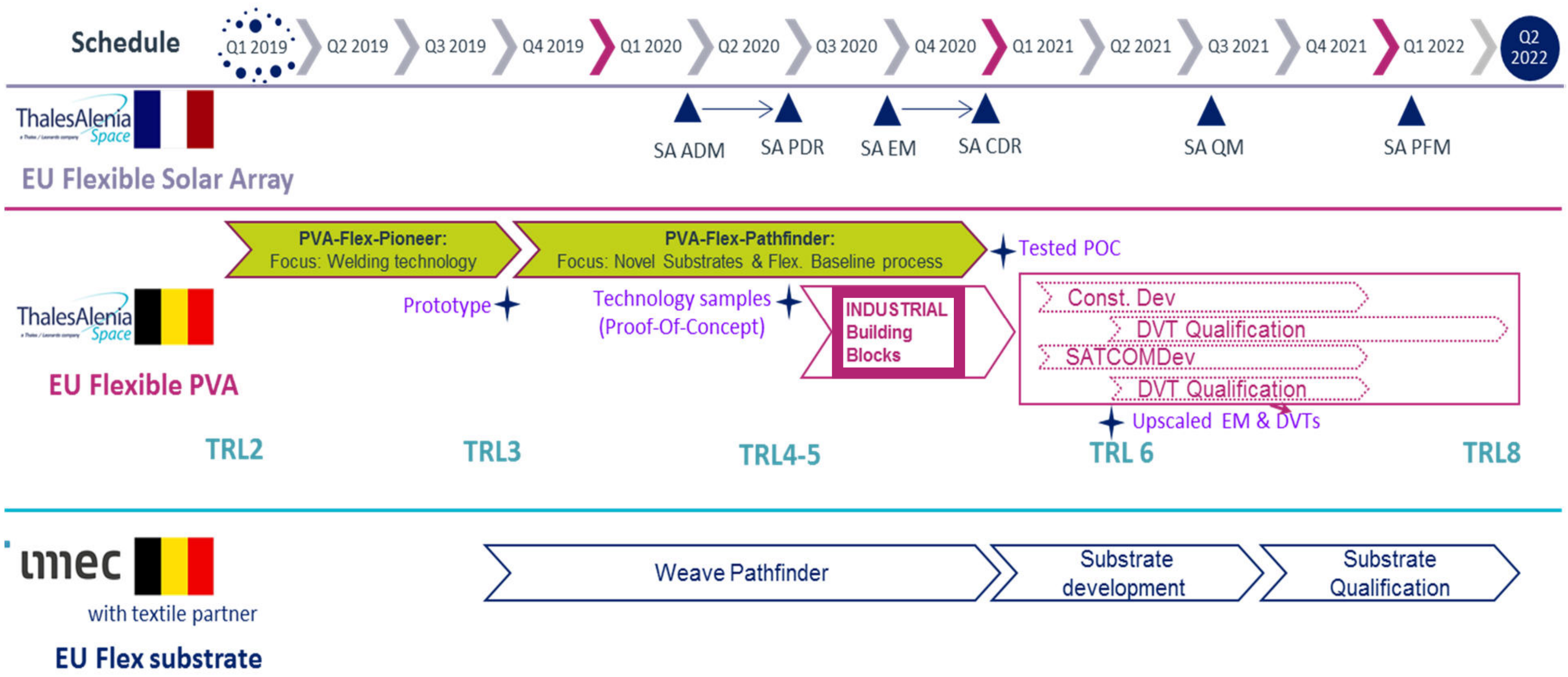
/// HW-2:

- 2 Pathfinder coupons based on ‘weave-2’ novel substrate
  - Coupon with ‘passive’ substrate (no integrated interconnectors)
  - Coupon with ‘active’ substrate (including integrated interconnectors)

/// HW-3:

- 1 Pathfinder coupon based on ‘weave-3’ novel substrate (= optimisation of weave-2 active substrate)

Development Plan: Flexible Solar Array - PVA & Substrate



Date: 27/11/2019
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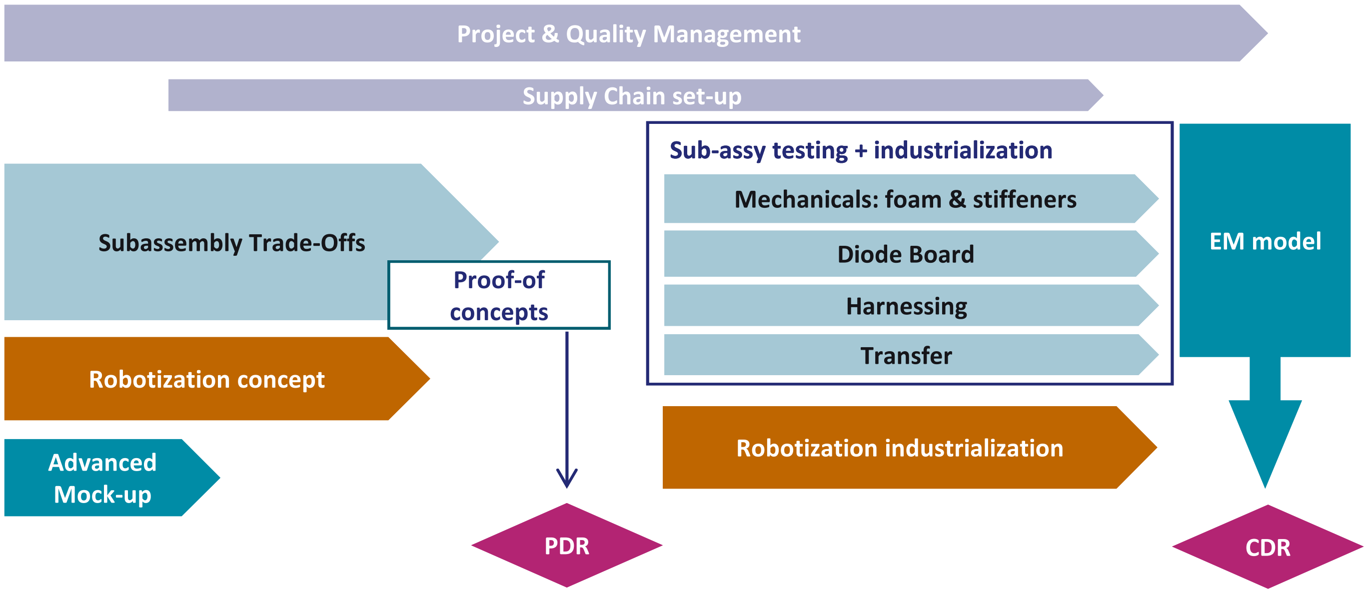
Template: 83230347-DOC-TAS-EN-008

PVA-FLEX Industrial Building Blocks: Work Logic

/// Objectives:

- Further trade-off & industrialization of PVA building blocks, including robotization
- Realization of Flexible EM PVA



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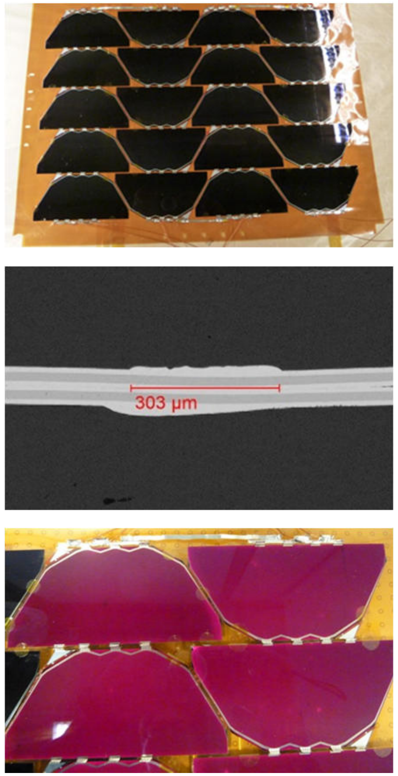
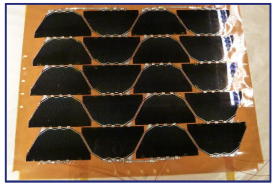
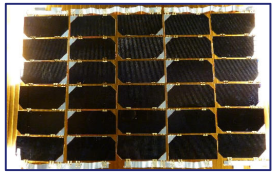
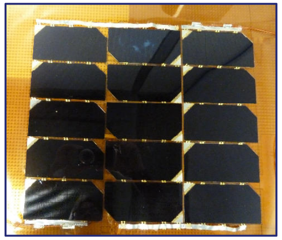
Overview of PVA-FLEX cost

Phase	Envisaged ESA program	Total cost (M€)	ESA price (M€)	Period
1: Flexible Pioneer	GSTP	0,2 M€	0,2	2018-2019
2: Flexible Pathfinder	GSTP	0,65 M€	0,5	2019-2020
3: PVA-Flex Industrial Building Blocks development (including representative EM before qualification phase)	ARTES CC (To be confirmed)	1,5 M€ (ROM)	ARTES CC funding expected: – 2,2M€	2020
4: PVA-Product Qualification (including need of extended temperature cycles)	ARTES CC (To be confirmed)	2 M€ /product (ROM)		2021

PVA-FLEX-PIONEER
FINAL PRESENTATION



Conclusions

/// De-risking of parallel welding technology

- From technology comparsison: parallel resistance welding chosen as baseline technology
- Process first optimization & characterization done with BWI & Amada
- Good results from shear testing. No significant damage to kapton observed (to be continued in Pathfinder)
- Welding table purchase ongoing ⇒ first tests planned Q1-2020. To be used within PVA-FLEX-Pathfinder

/// Introduction of CESI SCA in TAS portefolio:

- First welding tests on Ag/Invar interconnectors with flash gold were done prior to coupon manufacturing

/// Pioneer coupons

- Tooling was designed for kapton handling during manufacturing & transport
- 3 coupons were made: 1 based on Azur SCA, 2 based on CESI SCA
- Pioneer-CESI coupons didn't show ELM signal: more detailed investigation is ongoing to understand root cause
- Pioneer-AZUR coupon: after ELM/visual/Electrical testing at TAS-B, testing was successfully continued (outside Pioneer project):
  - Vibration & roll/unroll
  - Thermal cycling (as passenger)


QUESTIONS ?

LOG OF CHANGES AND APPROVAL

Révisions	Log of change - Description	Date
001	New Document	25-11-2019

Actors	Approval - Name and role	Date
Written by	Colicis Hugues	
Verified by	Dawidowicz Elie, Verdonck Julo	
Approved by	Das Johan	