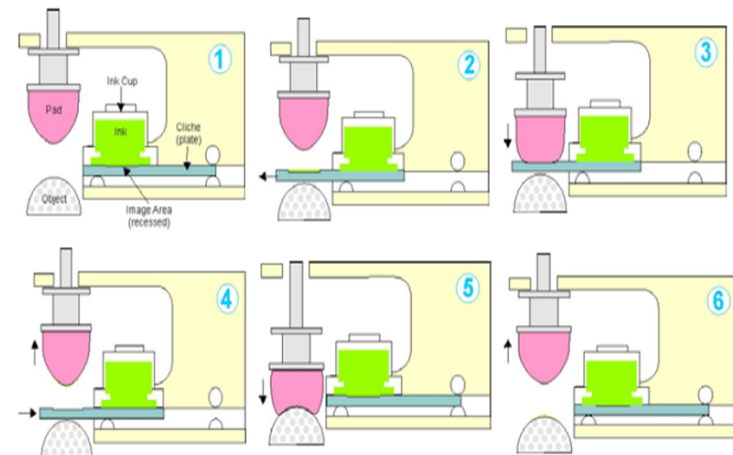
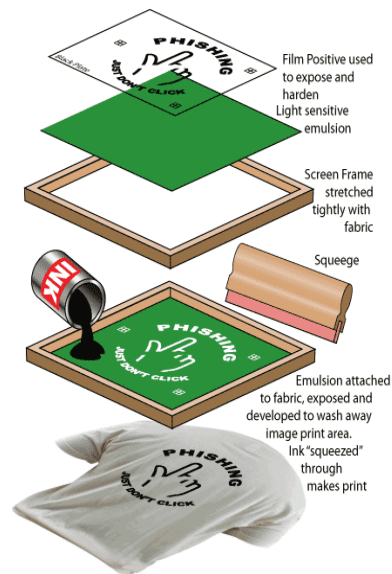


FORMAT round 1



Decoration



Main function: [to modify] [color of] [a surface]

SURFACES

Plastics: PVC (thermoplastic), ABS, thermosetting polymers

Metal: steel, stainless steel, painted steel, aluminum, chrome

Glass: vitroc ceramic, soda lime glass, colored (tinted) glass

Porcelain

Surface's shape: flat, 2D curved, 3D curved, perforated, textured surface

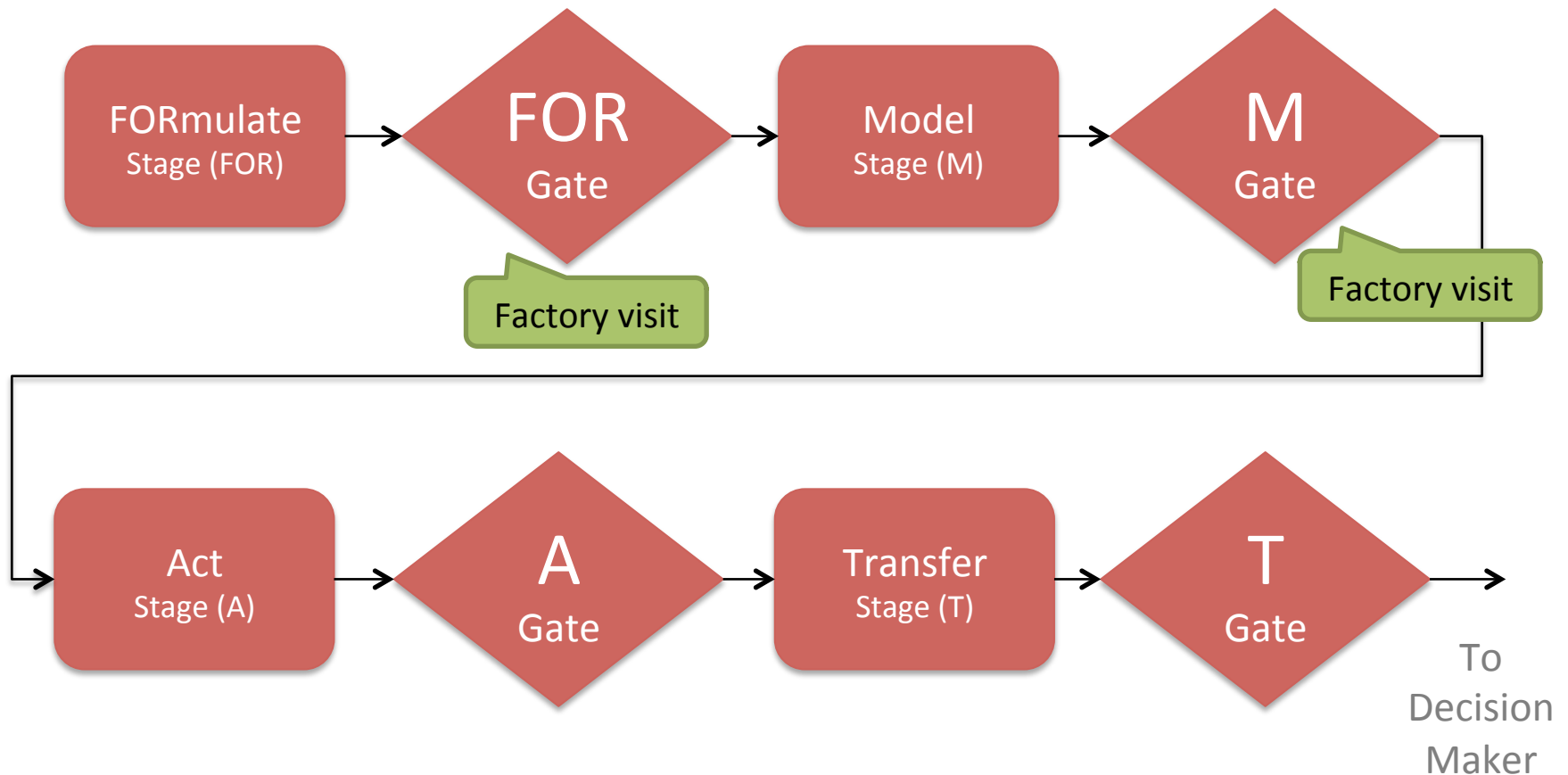
Question for Forecast

(Questions to be answered at the end of study)

What?	When? (time horizon)	Where? (market scope and geographic context)
<p>1. Which is the most promising decoration technology for achieving present and future product need (quality, flexibility, cost effectiveness)?</p> <p>2. Will decoration technologies be needed?</p> <p>3. Which will be the expected (estimated) evolution of Main Parameters of ink-jet and laser marking?</p> <ul style="list-style-type: none"> • When will inkjet technology be ready to substitute silk screening and pad printing for domestic appliances? • When will laser marking be able to produce colored marks in plastic? 	<p>in the future 5 to 10 years (2019-2024)</p> <p>indefinite</p>	<p>for all products:</p> <ul style="list-style-type: none"> • refrigerators; • ovens, • microwave ovens; • dishwashers; • washing machines, • dryers; • cooktops <p>at WHRIT factories in EMEA*</p> <p>-> for plastic surfaces</p>

* EMEA - Europe, Middle East, Africa

FORMAT Methodology: Stage-Gate process



FORMAT Methodology

from February 2 to April 2, 2014 (9 working sessions)

Stage / Gates	Meetings	Work Time
(FOR) Diagnose questions and plan project	4h	2 workdays
(M) Define the system for forecast and study contexts	4hx4	8 workdays
(A) Develop forecast for defined system and contexts	4hx5	8 workdays
(T) Prepare report and present results	4h 4h	3-5 workdays 1 workday

PWR:

Mateusz Slupinski (seconded to WHRIT), *Sebastian Koziolk*

WHRIT:

Luca Ruggeri (seconded to PWR)

Igor Kaikov

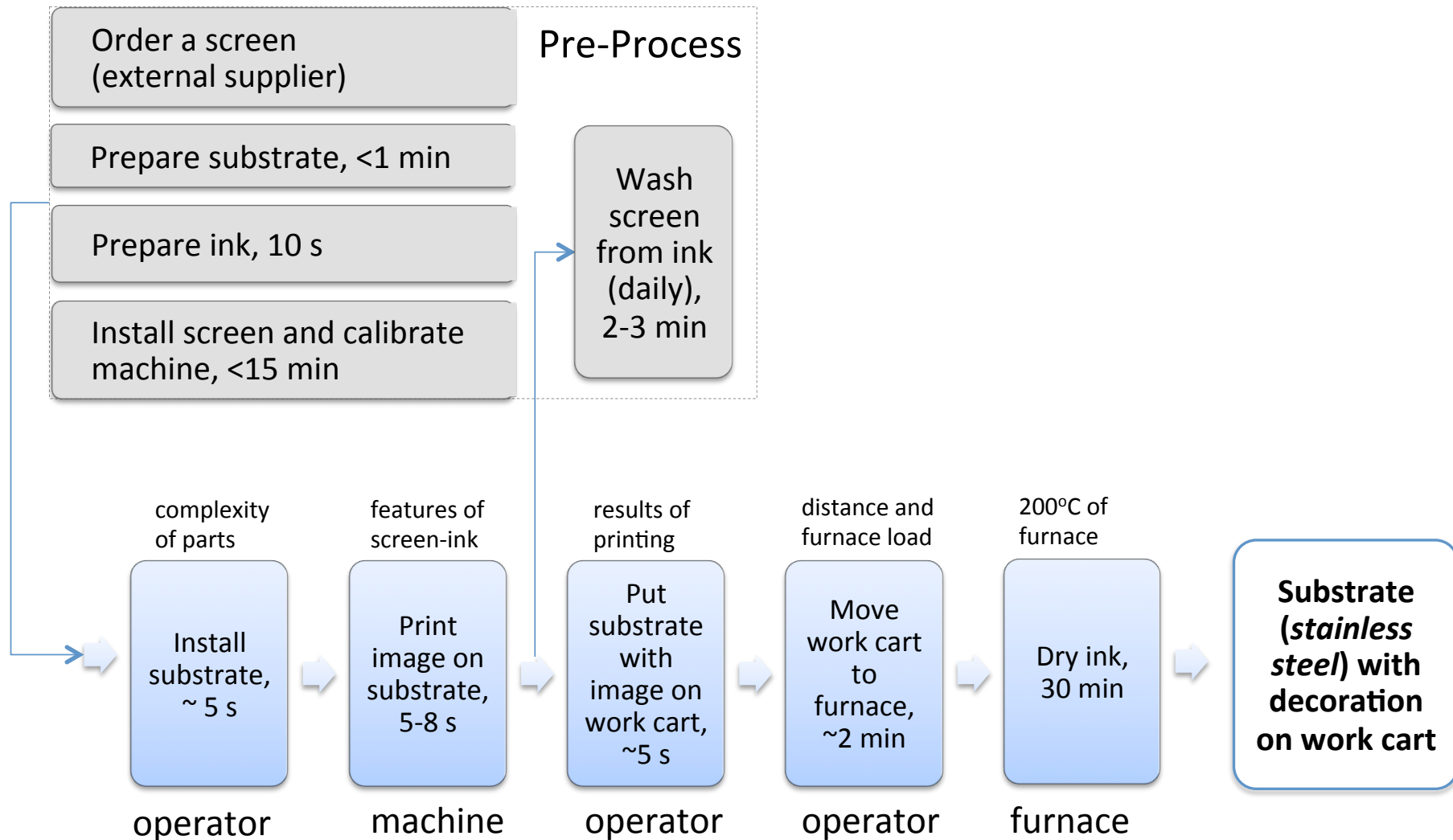
PoliMi:

Dmitry Kucharavy, *Christopher Nikulin*

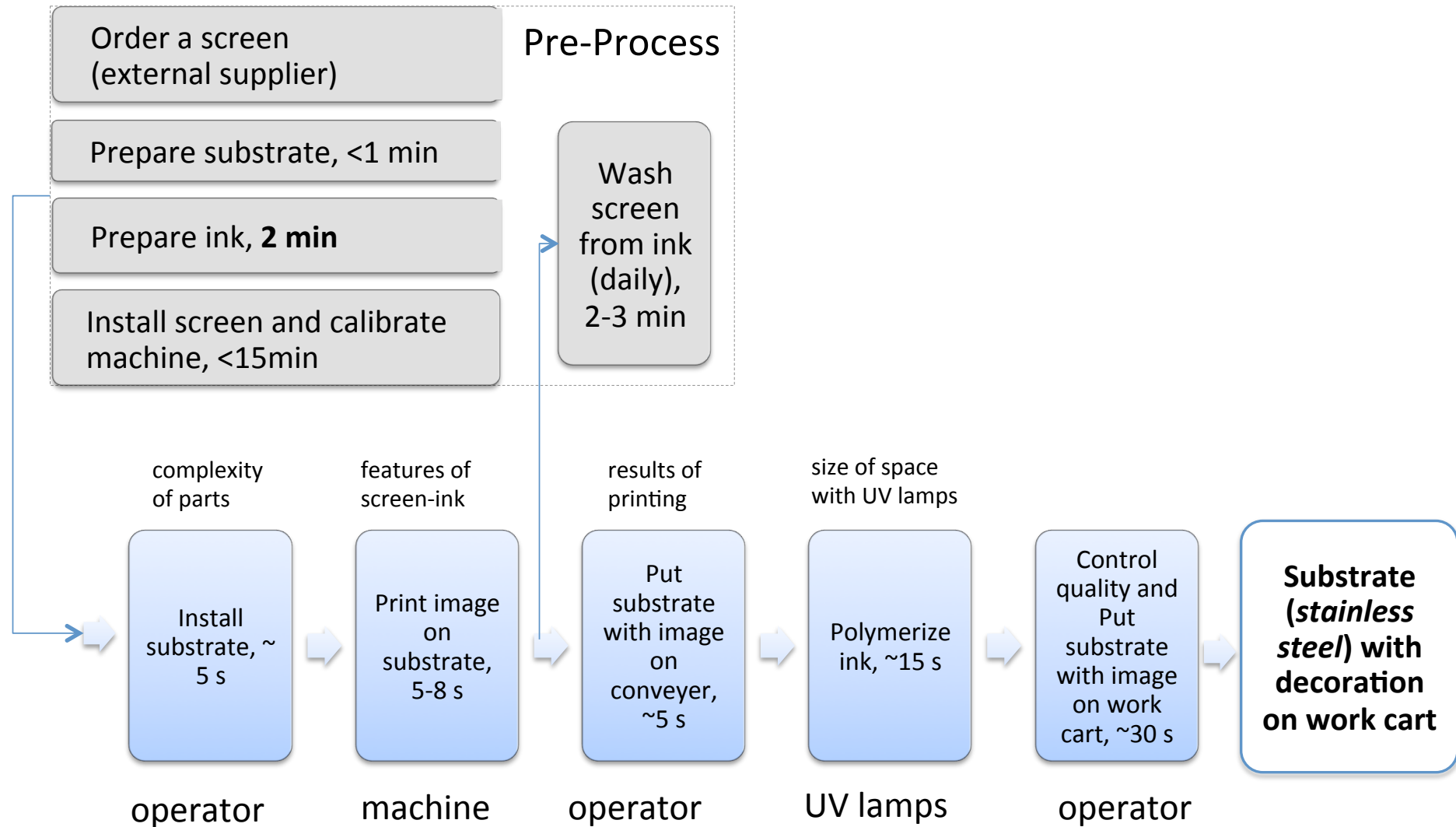
- Pierluigi Petrali
- Fabrizio Sella
- Marco Urbaz
- Fabio Moneta
- Michael Z. Cukier

Model of STF at the functional level

Functional model (1/4): silk screening = screen printing (static)



Functional model (2/4): silk screening = screen printing (UV)

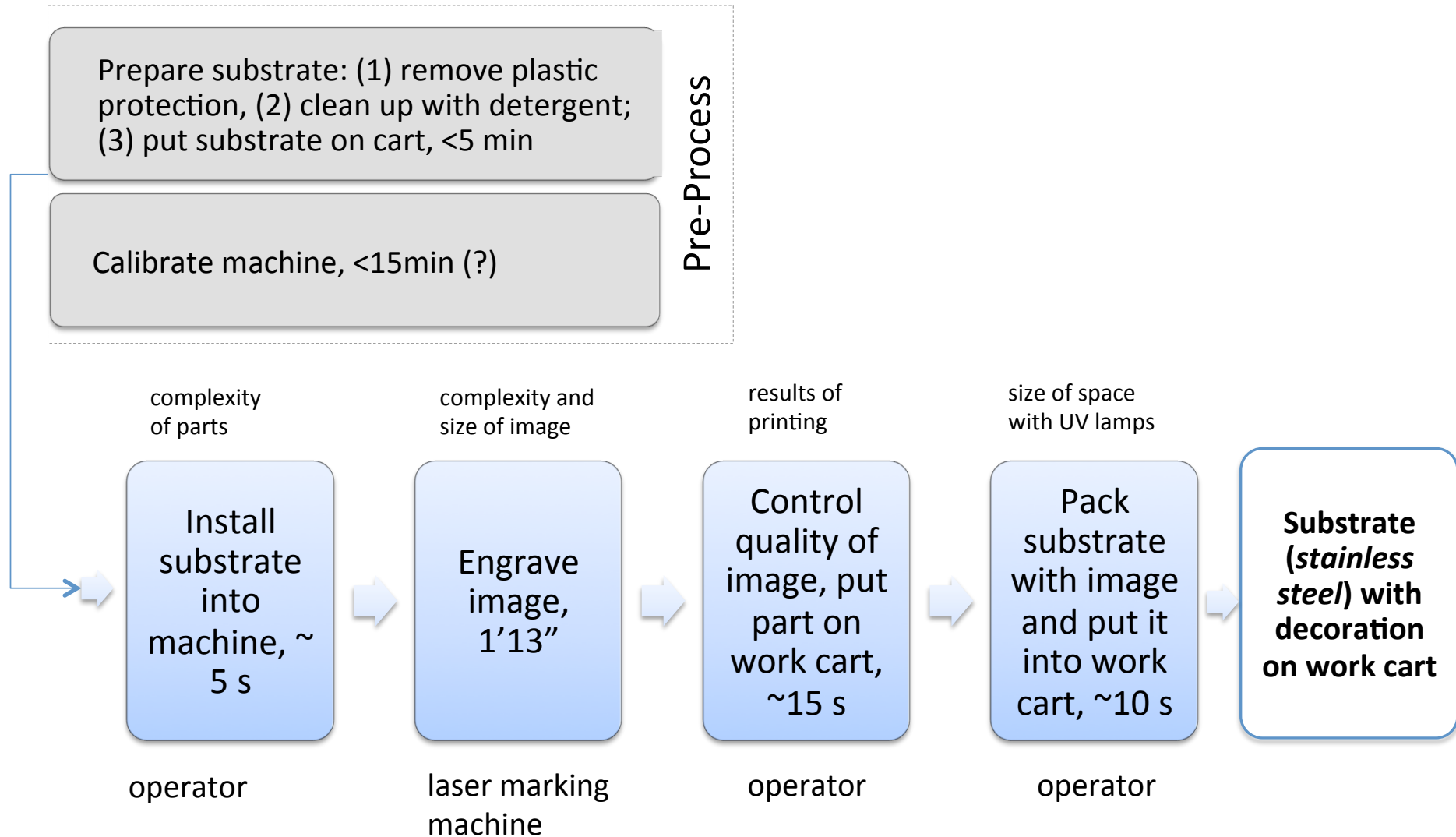


Source of information: factory visit on 06/03/2014, guided by: Ambrogio Rovera, Pierluigi Petrali
FORMAT 'Decoration' round 1

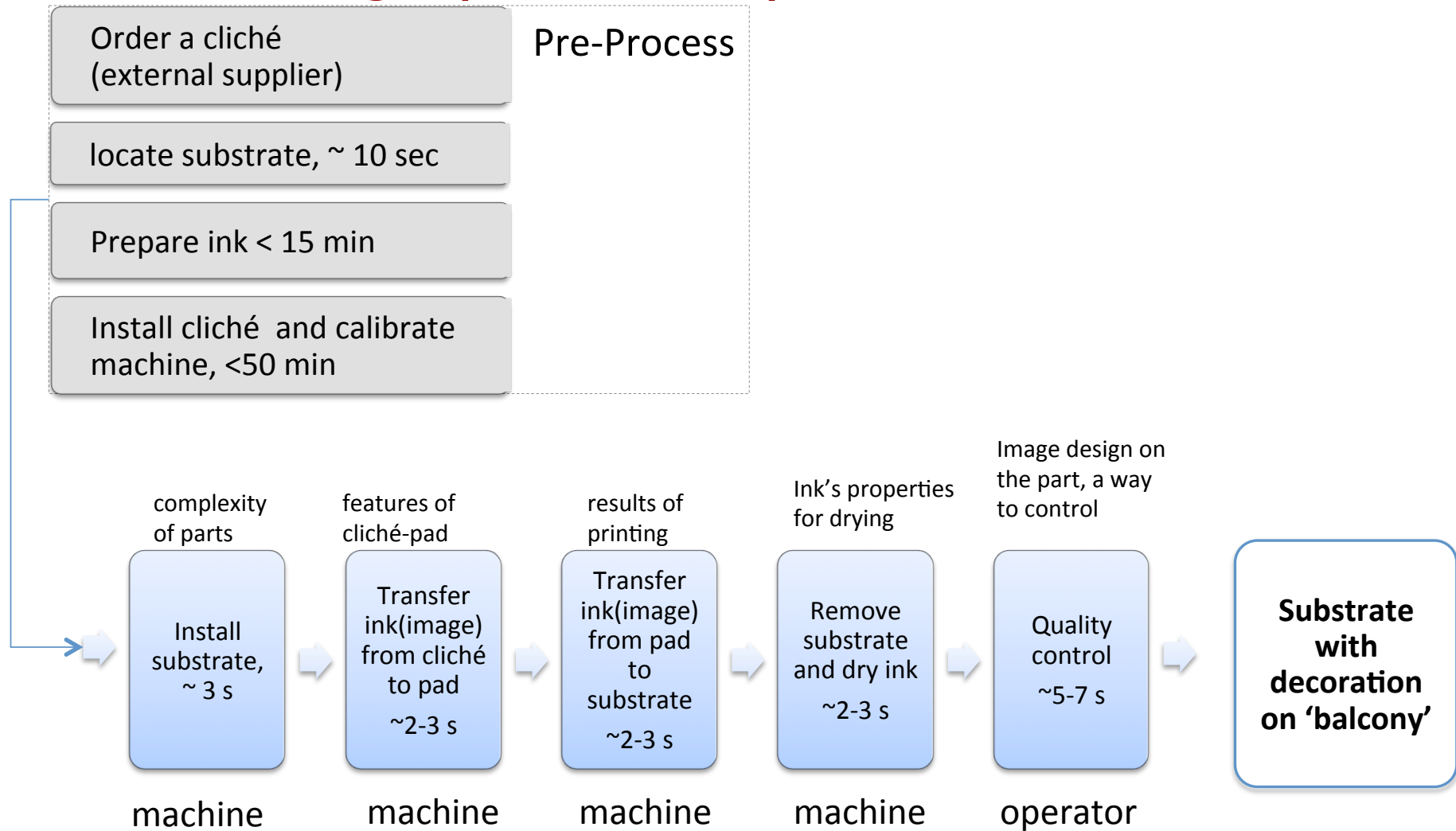
Pilot 2 – Team B: Decoration

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Functional model (3/4): laser marking

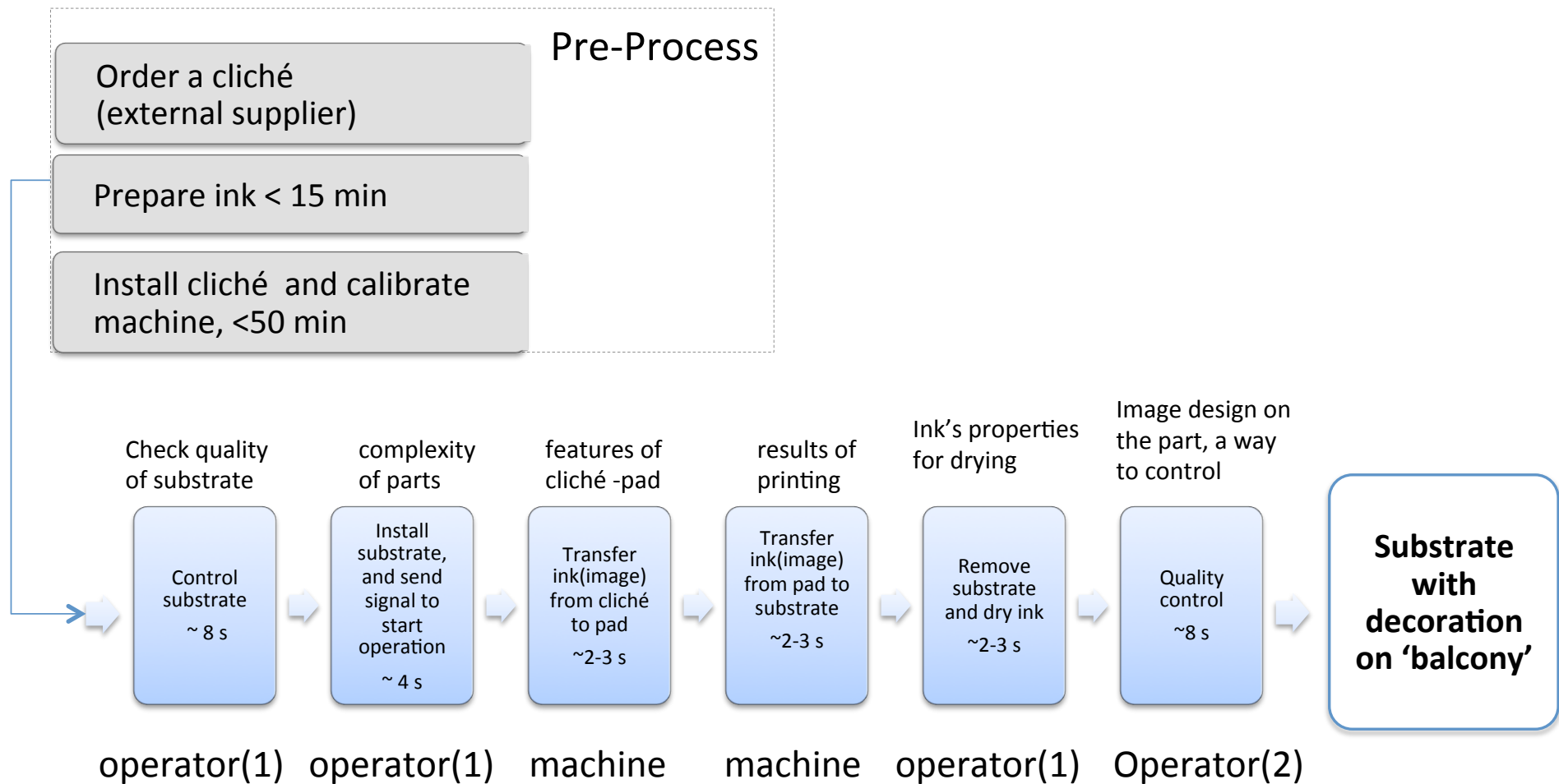


Functional model: Pad printing= (automatic)



[1] Visit #2, Whirlpool production line, 14/03/2014, guided by and explications delivered by Fabrizio Sella

Functional model: Pad printing= (semi-automatic)



[1] Visit #2, Whirlpool production line, 14/03/2014, guided by and explications delivered by Fabrizio Sella

Description of Competitive (Alternative) technologies and solutions

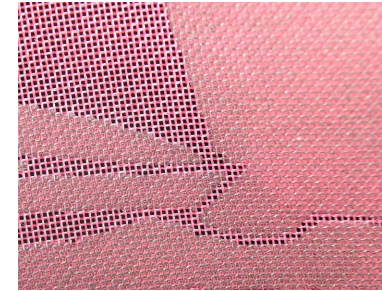
List of decoration technologies considered at WH:

1. silk screening (screen printing); IN/OUT
2. pad printing (tampography); b) multi-stations, c) with semi-automation; IN/OUT
3. hot stamping; IN/OUT
4. laser marking (laser graphic imaging); IN
5. chemical etching (etching on metals; etching on glass); OUT
6. Ceramic paste; OUT
7. Inkjet printing; NOT YET USED

IN/OUT refers to utilization of a particular technology IN Whirlpool factories or only as an element bought OUT side of Whirlpool.

Competitive (Alternative) (1/7): silk screening (screen printing)

Screen printing is a printing technique that uses a woven mesh to support an ink-blocking stencil to receive a desired image.



A macro photo of a screen print with a photographically produced **stencil**. The ink will be printed where the stencil does not cover the substrate*.

Disadvantages identified for silk screening

1	It is difficult to apply for curved surfaces, when radius is small
2	High time consumption for pre-process (create design, molds, films, etc)
3	Only one color can be printed at the same time
4	Multiple stages to add additional color in the image (one color more = one machine more)

[1] BoP, Herreria, J. L. Bill of Process Decorations for Plastic, Glass & Metal Substrate (2011). Benton Harbor: ADVANCED MANUFACTURING, Whirlpool. Confidential

[2] Session 1.2, 27-02-2014, Whirlpool Cassinetta.

[3] http://en.wikipedia.org/wiki/Screen_printing#Screen_printing_press

Competitive (Alternative) (2/7): pad printing

Pad printing is a printing process that can transfer a 2-D image onto a 3-D object. This is accomplished using an indirect offset (gravure) printing process that involves an image being transferred from the cliché via a silicone pad onto a substrate.

Disadvantages identified for pad printing

1	Inadequate resolution and esthetic for large surface cause by pressure of the machine.
2	No metallic effect (may be an important factor for customer decision), limited flexibility to prepare colors .
3	It is necessary pre-install films and clichés according each new image.
4	Waste of films and clichés due to iterations for each new image.

[1] BoP, Herreria, J. L. Bill of Process Decorations for Plastic, Glass & Metal Substrate (2011). Benton Harbor: ADVANCED MANUFACTURING, Whirlpool. Confidential

[2] Session 1.2, 27-02-2014, Whirlpool Cassinetta.

[3] Pad-printing, description process: available :http://www.teca-print.ch/eng/Padprinting/Tampondruckverfahren_E_706-000-240.pdf

[4] http://en.wikipedia.org/wiki/Pad_printing

Competitive (Alternative) (3/7): hot stamping

Hot stamping is a dry printing method of lithography in which pre-dried ink or foils are transferred to a surface at high temperatures.

Main feature of hot stamping at WH: – applied for making a metal gloss decoration on substrate; – hot stamp pressing; – pressed cliché; – controllable pressing force; – applicable on plastics such ABS, polypropylene, enameled steel; – initial set up is complex.

Pros	Cons
Change over time is under 5 min	impractical for reworking
Cycle time	Low operation cost effectiveness
Non-polluting process because paint is dry	High scrap rate
Durability, chemical resistance, abrasion resistance	Long change over under 1 cycle
Relative low investment	Not easy for maintenance
Chrome/metal appearance	Control of pressure power
Resolution	Requires a cliché
Environment friendly green	Initial set up is complex
	0.2 mm raised geometry is recommended for optimum hot stamping transfer

[1] BoP, Herreria, J. L. Bill of Process Decorations for Plastic, Glass & Metal Substrate (2011). Benton Harbor: ADVANCED MANUFACTURING, Whirlpool. Confidential

[2] Wikipedia http://en.wikipedia.org/wiki/Hot_stamping

Competitive (Alternative) (4/7): laser marking

The laser beam modifies the material surface, creating permanent marks without removing material or impacting surface integrity². At WH it is applied for *making digitally processed decoration with zero change over time*.

Pros	Cons
<ul style="list-style-type: none">• zero change over (no tooling change required) – 1/1 principle in manufacturing possible to apply• Durability• Lower scrap rate• Environment friendly green• Range of application from small to large• Resolution• Change over over one cycle	<ul style="list-style-type: none">• Costly maintenance• Costly utilities• high cycle time• Higher level of expertise for maintenance• Exchange pieces (spare parts) are unique for particular application• Chemical resistance worse then silk screening• Low operation cost effectiveness• No color complexity management• No chrome/metallic appearance

[1] BoP, Herreria, J. L. Bill of Process Decorations for Plastic, Glass & Metal Substrate (2011). Benton Harbor: ADVANCED MANUFACTURING, Whirlpool. Confidential

[2] <http://www.ulsinc.com/>

Competitive (Alternative) (5/7): chemical etching

Etching refers to the technique of creating decoration on the surface of metal or glass by applying acidic, caustic, or abrasive substances.

Pros	Cons
<ul style="list-style-type: none">• Cheap, ¹• Relative low investment ³• Lower scrap rate ³• Ease of maintenance ³• almost no damage due to purely chemical nature, ¹• highly selective ¹• Durability, chemical resistance, abrasion resistance ³• Relative quick change over ³• Range of application small to large ³	<ul style="list-style-type: none">• Inadequate anisotropy, ¹• inadequate process control (temperature sensitivity), ¹• inadequate particle control, ¹• high chemical disposal costs, ¹• difficult to use for small parts. ¹• No color complexity management ³• No chrome/metallic appearance³• Limited substrate application³• No environment friendly green ³• Long cycle time ³• Long change over under one cycle ³

Isotropic² – Etching proceeds at equal rates in both horizontal and vertical direction

Anisotropic² – Etching proceeds faster in one plane than in another

Selectivity² – The ability of the etch process to distinguish between the layer to be etched and the material not to be etched

[1] For wet chemical etching by Alan Doolittle, PhD, Georgia Tech, <http://users.ece.gatech.edu/~alan/> , Lecture 11 Etching Techniques
Reading: Chapter 11

[2] Isotropic, Anisotropic, Selectivity – from: Maricopa Advanced Technology Education Center, part of the Academic Affairs Division, Maricopa Community College District

[1] BoP, Herreria, J. L. Bill of Process Decorations for Plastic, Glass & Metal Substrate (2011). Benton Harbor: ADVANCED MANUFACTURING, Whirlpool. Confidential

Competitive (Alternative) (6/7): inkjet printing

Inkjet printing is a type of computer printing that creates a digital image by propelling droplets of ink onto paper, plastic, or other substrates.

Expected application at WH: To make digitally processed decoration in wide scale of color with up to photorealistic resolution.

Pros	Cons
<ul style="list-style-type: none">• Graphics resolution (Photorealistic)• Entire surface can be covered• It is possible to apply on small surface• Digital image process (pre-process) is less than 30 min• customization of image with real-time data• Different kind of thickness for graphics• Diversity of colors applied on one surface• Gradient effect is possible• High flexibility for different types of images• Adequate cycle time [s/pcs]• Adequate change over time	<ul style="list-style-type: none">• Relatively high process time for long surface.• Number of colors is constrained by cartridge from suppliers (It is not possible to create a new colors)• Ink performance is not adequate for corrosion• It's not possible to make the metallic colors

[1] Ubraz M. Inkjet technology, Whirlpool Cassinetta October, 2013

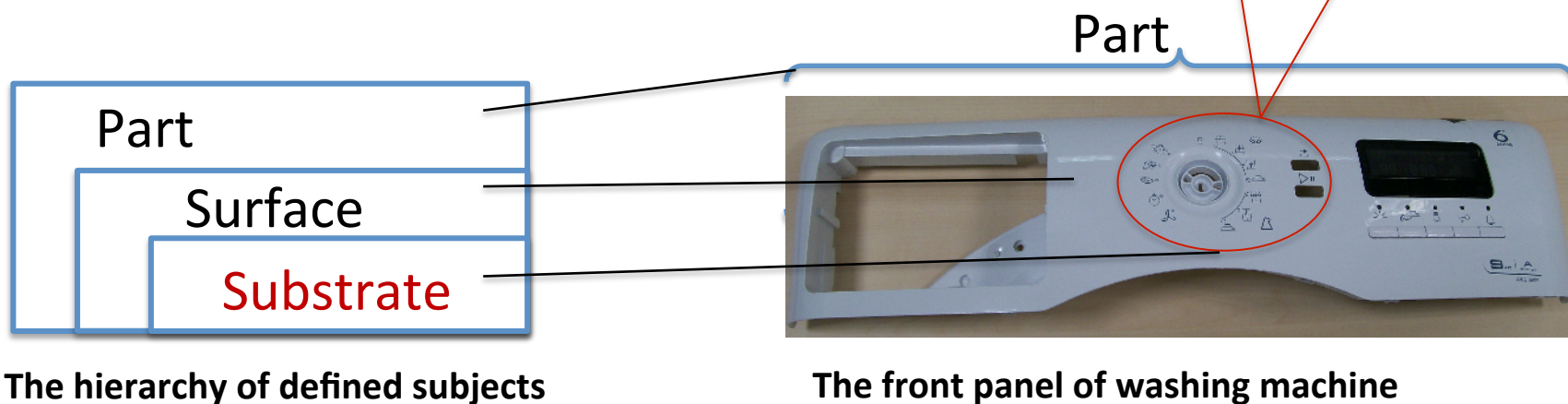
Description for STF

Definition of surface and substrate

Part – A part of something is one of the pieces, sections, or elements that it consists of. [Collins COBUILD dictionary]

Surface – it is a layer on the part where substrate is located.

Substrate – an area of the surface on which an image (decoration) printed. the hierarchy definitions.



The hierarchy of defined subjects

The front panel of washing machine

System operator: super-systems

2004

1. Home appliances from different companies in one home
 - Partially integrated
2. WH appliances with less information
3. Control Panel (CP) with less information and less control options
4. Users manipulate
 - No touch-screen experience for user
5. To attract client
 - Not so much concern about energy saving
 - Not so much attention to esthetic
 - New options less important
6. recyclability of home appliance was less important
7. Gradation of color was not relevant.
8. In it not possible create customized CP
9. Decoration of CP mostly by printed.
10. Whirlpool authenticity (brand, logo, look of products) was less recognizable.

2014

1. Home appliances around (home)
 - Esthetically similar from 2 or 3 companies;
2. WH appliances
 - Manual print and pdf
3. Control Panel (CP) production and use
4. Users⁵ manipulate
 - with CP - to setup Home appliances (learn how to)
5. To attract client
 - esthetic,
 - novelties
 - information
 - chemical resistances)
6. recyclability of home appliance growth in importance
7. Gradation of color it is possible with ink-jet (not applied in WH)
8. It is possible to create customized CP in high-end appliances.
9. Combined decoration of CP (display + printed)
10. Whirlpool authenticity (brand, logo, look of products) is recognizable.

2024

1. Home appliances from one hand (e.g. IKEA+WH)
 - Integrated esthetically, electronically and by data-information
2. WH appliances provide more information (more sensors & data)
3. Control Panel (CP) has to delivered more information and control
4. Users manipulate (easy to setup)
 - More touch-screening experiences.
 - New Options are attractive
 - Easy to use.
5. To attract customer
 - esthetic,
 - novelties,
 - **easy to use**,
 - smart energy consumption;
 - improved chem. resistances
6. Recyclability will be more important
7. Gradation of color in the design of CP??
8. User can create their own CP for more products
9. Most of decoration of CP with an electronic User-Interface (multi-language)
10. Whirlpool authenticity (brand, logo, look of products) more recognizable.

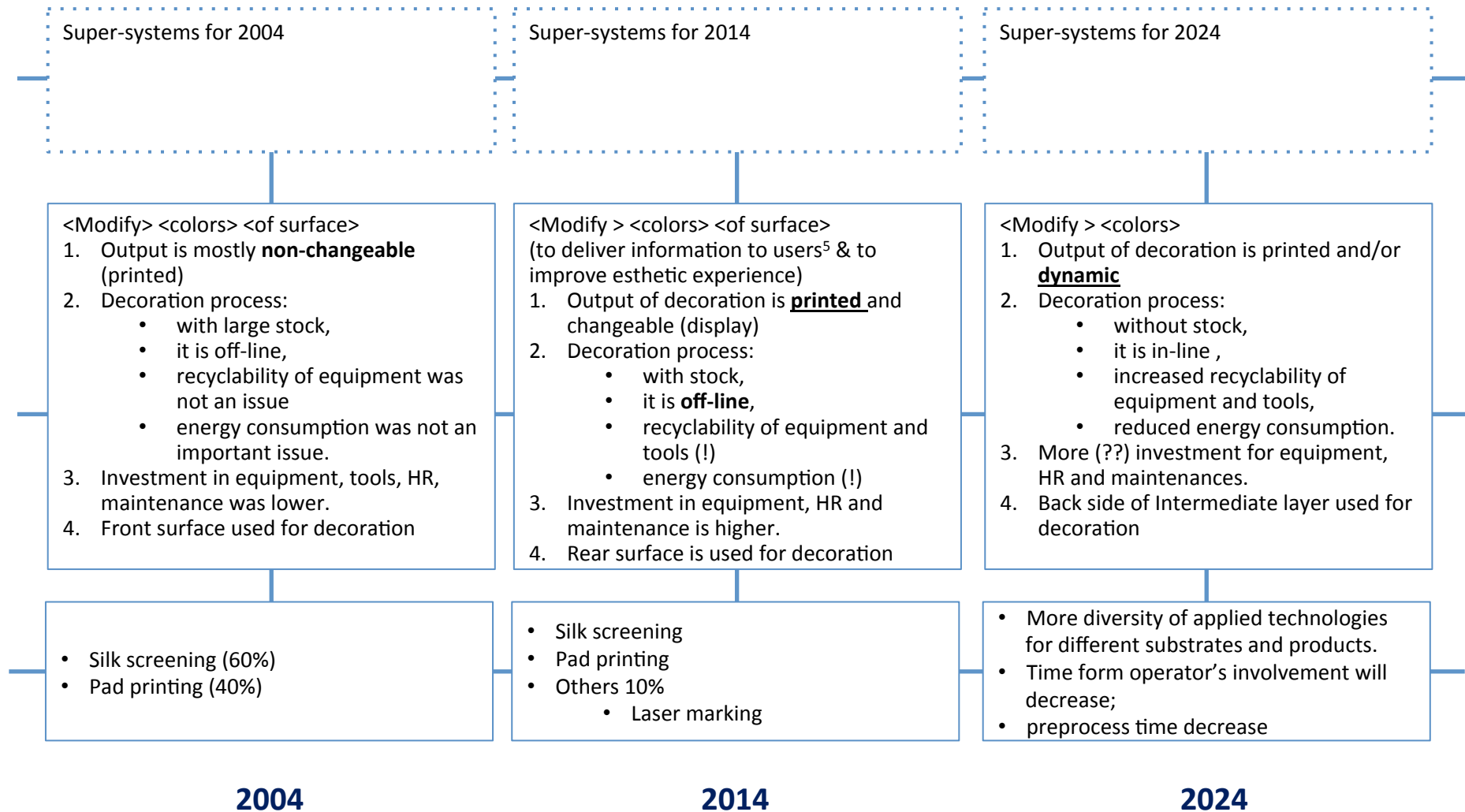
² Herreria, J. L. Bill of Process Decorations for Plastic, Glass & Metal Substrate (2011). Benton Harbor: Advanced Manufacturing, Whirlpool. Confidential

³ Session 1.2, 27-02-2014, Whirlpool Cassinetta.

⁴ Inkjet technology Marco Urbaz, Cassinetta, October, 2013

⁵ Man, woman, elderly people, teenagers, kids

System operator: system and sub-systems



⁵ Man, woman, elderly people, teenagers, kids
FORMAT 'Decoration' round 1

Measure of Performance & Expenses for STF and for Competitive Solutions

Six decision criteria (3 for performance and 3 for expenses):

1. Controllability of printing process: more control on image
2. Flexibility
3. Productivity of process (pcs/h)
4. *Maintainability (non-working, h)*
5. *Integration level with production line*
6. *Cost of equipment, operation and human resources (EUR)*

It is suggested to measure the growth and competition of decoration technologies by **number of parts** produced (decorated) **per Quarter** with a particular technology starting from 2004 (2009 at least) at European factories.

Reference documents for required data:

1. DoP – Declaration of Production,
2. OEE – Overall Equipment Efficiency

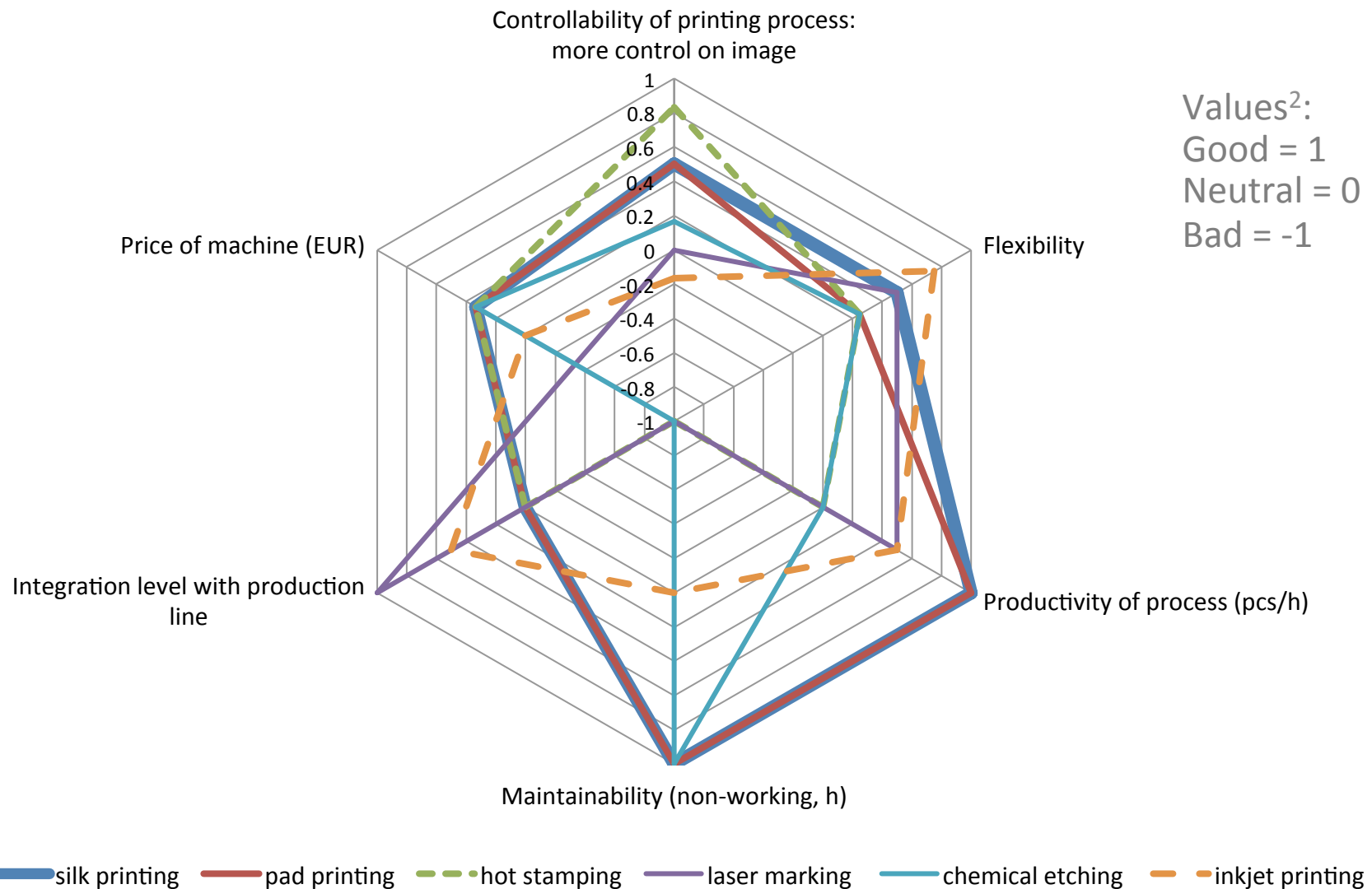
Summary for Competitive (Alternative)

Content removed for confidentiality reasons

Summary for Competitive (Alternative)

Content removed for confidentiality reasons

Summary for Competitive (Alternative)



² Herrera, J. L. Bill of Process Decorations for Plastic, Glass & Metal Substrate (2011). Benton Harbor: Advanced Manufacturing, Whirlpool. Confidential

TEES-constraints to STF

TEES = Technological, Economic, Environmental, Social

TECHNOLOGICAL	ENVIROMENTAL
<ul style="list-style-type: none"> - Accessible to produce different kind of look and surfaces. (super-system) - Automation of production, less supplementary operations (such as prepare the ink and so on). (super-system) - Time to make decoration. (sub-systems) - Ambient conditions (temperature, humidity, level of UV, conditions of CP surface ...) should be stabile during production of decoration. (sub-systems) - Production of decoration should be integrated with main production line. (e.g. automation). (super-system) - performance of modified color (abrasion, chemical resistance, durability). (super-system) - material of cliché causes environmental impact. (super-system) 	<ul style="list-style-type: none"> - Recyclability of equipment, tools, area, HR. (system) - material and substances has to be compatible with production process, home environment and HR, H&S (Health & Safety) ([1], page 14). (super-system)
ECONOMIC	SOCIAL
<ul style="list-style-type: none"> - Initial investment in equipment, tools, area, human resources (HR). (system) - overall cost of running equipment (normative cost, before called SIC – S.. Industrial Cost). (system) - Investment for training HR. (system) - Low production cost. (super-system) - Amount of energy used for entire production process of WH appliance. (super-system) - Investment for maintenance. (system) - How much energy is consumed to modify colors? (system) 	<ul style="list-style-type: none"> - Result of decoration understandable for different groups of users (affordance). (super-system) - Results of decoration has to be customizable (super-system) - Whirlpool authenticity has to be recognizable. (super-system) - Education of operator in production process (adjustments, pre-installment). (super-system) - Quality of the image has to be attractive for users. (super-system)

[1] BoP, Herreria, J. L. Bill of Process Decorations for Plastic, Glass & Metal Substrate (2011). Benton Harbor: ADVANCED MANUFACTURING, Whirlpool. Confidential

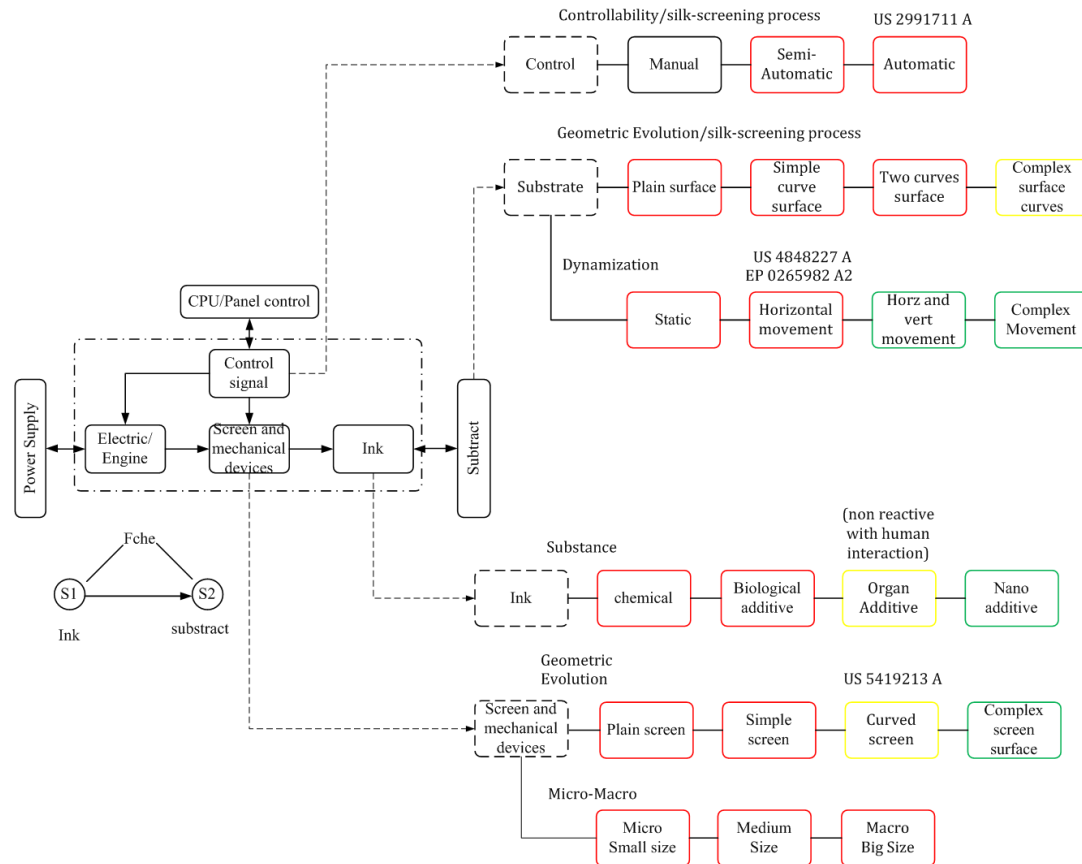
[2] Meeting 27-02-2014, Whirlpool Cassinetta.

[3] Inkjet technology Marco Urbaz, Cassinetta, October, 2013

Application to pad-printing and silk-screening technology

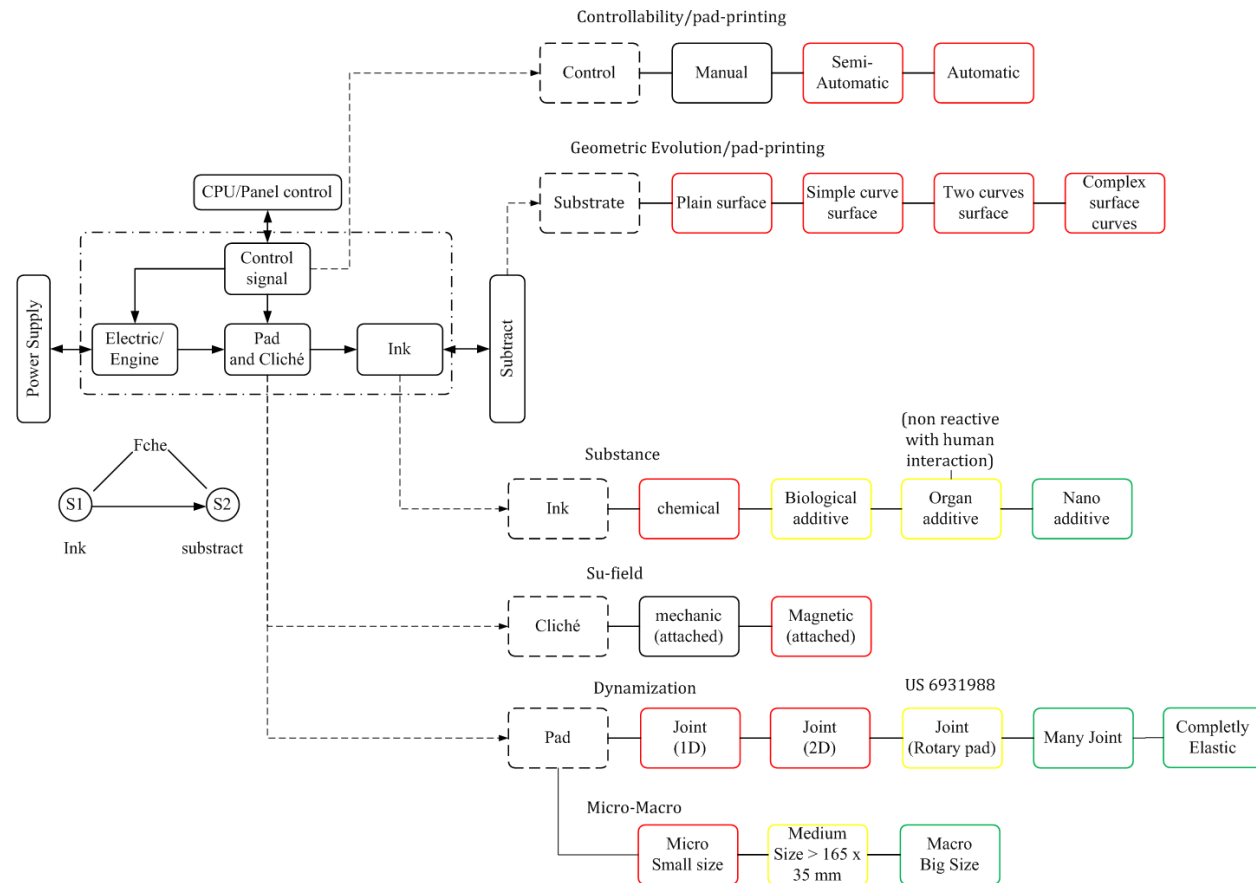
- **Recognize relevant patterns and analogical reasoning for envisioning future with patterns of evolution.**
 - Definition of Minimum Technical System for pad-printing and silk-screening
 - Recognize patterns for Tools, transmission, control and object.
- **Check coherence of the envisioned future with the available information about the context.**

Analogical reasoning for envisioning future with patterns of evolution: Silk-Screening



- [1] Patent n° US 5419213 (A) (1993) "Apparatus and method for the silk-screen printing of multiple curved peripheral surfaces of an article defined by multiple curved peripheral surfaces"
- [2] Patent n° US 2991711 (A) (1954) "Fully automatic silk-screen printing machine movement of surface"
- [3] Patent n° EP 0265982 (A2) (1986) "Machine for the multi-colour silk-screen printing of cylindrical containers in general"
- [4] Patent n° US 4848227 (A) (1981) "Device for the silk-screen printing of cylindrical objects having an elliptical cross-section"
- [5] Inkcups Now (March-2014), <http://www.inkcups.com/>
- [6] <http://www.triz.co.kr/TRIZ/frame.html>
- [7] Glenn Prestwich (2007). Instant insight: Organ printing, Highlights in Chemical Biology, 5.

Analogical reasoning for envisioning future with patterns of evolution: Pad-Printing



[1] Dongguan Ruida Machinery And Equipment Co., Ltd. (March-2014) /<http://dgnewman.en.alibaba.com/>

[2] Inkcups Now (March-2014), <http://www.inkcups.com/>

[3] CarePrint (March-2014) <http://www.padprinting.in/pad-printing-machine/>

[4] Patent n° US 6931988 (2004) "Rotary head pad printer"

[5] <http://www.triz.co.kr/TRIZ/frame.html>

[6] Glenn Prestwich (2007). Instant insight: Organ printing, Highlights in Chemical Biology, 5.

Check coherence of the envisioned future with the available information about the company context

Technology	Minimum Technical System	Description of the past solution and patterns	Expected benefits
Both technologies	ink	Increase the ink performance using different additive: Biological-ink is a ink that not produce environmental damage; Organ-ink is a ink that non-react with human interaction, nano-ink are possible future ink with new properties.	Drying time, quality of image
Both technologies	Substrate	Geometric evolution: Complexity of the shape surface has been increased given customers' demands.	Flexibility of the process
Silk-screening	control	Controllability: currently, there are automatic silk-screening, but process can still reducing the time consumption.	Process and pre-process time
Silk-screening	Substrate	Dynamization: There are some silk-screening machines capable to move the substrate in order to improve the decoration process.(e.g. moving the substrate is possible to print curve surface)	Flexibility of the process

Check coherence of the envisioned future with the available information about the company context

Technology	Minimum Technical System	Description of the past solution and patterns	Expected benefits
Silk-screening	Screen	Dynamization: Some silk-screening machines have a dynamic screen capable to track specific movement(e.g. horizontal).	Flexibility of the process
Pad-printing	Pad	Dynamization: Some pad-printing machines have a dynamic pad capable to track specific movement(e.g. vertical, horizontal and angles).	Flexibility of the process
Pad-printing	Pad	Micro-Macro: Size of the pad has been increased in the last year, however there some limitation in terms of ink performance.	Flexibility of the process
Pad-Printing	Cliché	Substance-Field involvement: In the past, the cliché was attached at the machine using different types of nuts and bolts , now the cliché is magnetic in order to reduce the pre-process time.	Flexibility of the process

See slide's notes too.

Analysis of the functional models (stage M) using Law of ideality increase [TRIZ]: towards ideal machine and ideal process

Features, (functionalities in bold; expenses in regular)

Controllability of printing process, more control on image	Full range of color management including metallic, performance maintained during entire time of use by users of a final appliance,
Flexibility	Digital printing (no image preparation), change over $t=0s$, change over time for a part type $t=0s$
Productivity of process [pcs/h]	Cycle time close to single color silk screening, no scrap
Maintainability [non working, h]	No down time for maintenance like laser marking, towards self-maintaining
Integration level with production line	Cycle time of decoration should be coordinated with cycle time of production line
Price of machine [EUR]	Investment to new technology should be lower, below alternatives (delivering the same result), operation cost should decrease, environmental impact should be minimized

Solutions addressing limiting resources

Limiting resources	Solutions
Time of process to modify the color	Time below cycle time of production line
Time for ink drying	UV curing with capacity for large size (or many) parts, time below cycle time of decoration
Radius of substrate's surface	Decoration tool maintains a fixed distance to any surface shape;
Area of contact between ink and substrate	Decoration and substrate are (tightly linked → are unified → are one)
Extent of ink's ability to attach to substance	Deep attachment, on back surface, inside substance

The oxidation time of the metal surface.

What are the reasons preventing the adoption of the Next-technology with required features?

1. **Diversity of performed decorations** demands different characteristics for applied technologies. Therefore, from business perspectives it is unlikely to satisfy all diversity of decorations by just one technology.
2. **Replacement of technologies** is long-term improvement process; it has to be done in accordance with plan of renewal of equipment and production plans of Home appliance.
3. In order to run *innovative technologies* for decoration (e.g. like inkjet printing with “flexible” ink on 3D substrates) **long-term investments into HR** are required.
4. Requirements to perform **decoration in many languages** (particularity of EU market) put *Flexibility* and *Integration level with production line* to the first-importance places for future products of WH.
5. Decision about investments into **In-house technologies** and **Out-sourcing** production is difficult to predict without knowing long-term strategy about production and development of WH.