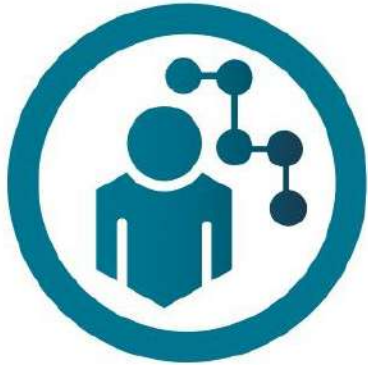Adaptive Automation in Assembly
For BLUE collar workers satisfaction in Evolvable context

A4BLUE

INDUSTRY IN THE AEROSPACE DOMAIN: Airbus and Héroux-Devtek Spain use cases in A4BLUE project
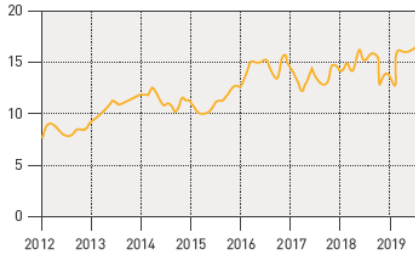
AEROTECH EUROPE - Bordeaux 25/09/2019

HÉROUX-DEVTEK GROUP

LISTED ON TSX SINCE 1986 (HRX)

16 INSTALLATIONS

6 in CANADA

5 in USA

3 in UK

2 in SPAIN

WORLD´S 3rd LARGEST

PRODUCER OF LANDING GEAR

1,764 EMPLOYEES

Guidance for FY 19: $460 Million
Guidance for FY 22: $620 Million

HÉROUX-DEVTEK SPAIN

CESA ahora es parte de / now is part of HÉROUX DEVTEK
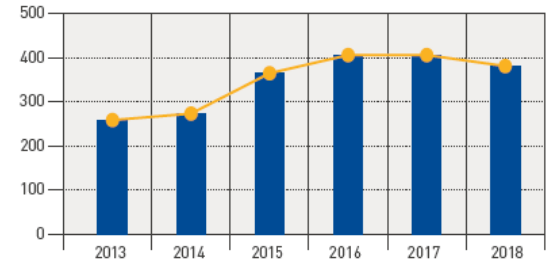
326
EMPLOYEES

+150
PROGRAMS

38.500 m2
MANUFACTURING SQM
(MADRID & SEVILLE)

15% R&D of SALES
ANNUAL INVESTMENT

CUSTOMERS IN
11 COUNTRIES

HÉROUX-DEVTEK SPAIN

https://vimeo.com/360231253
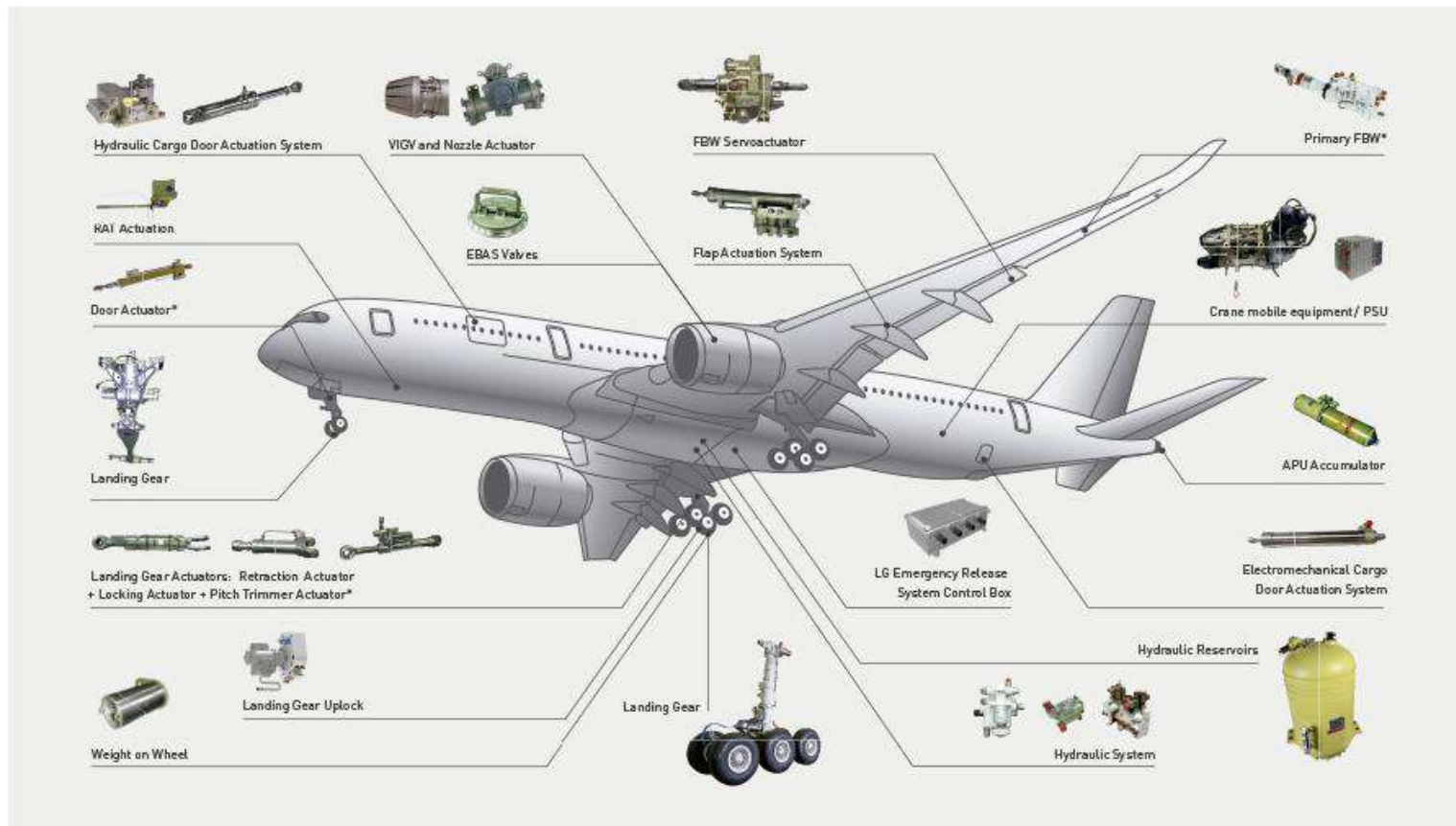
Put together workers and AUTOMATION mechanisms to take advantage of each others strengths

+

Put together workers and context-aware ADAPTATIVE ASSISTANCE TOOLS

TO

Increase worker SATISFACTION and workability

Increase productivity and overall PERFORMANCE

Long term socio-economic sustainability

A4BLUE involves 4 use case scenarios ...

INDUSTRIAL PILOTS

AIRBUS | TOULOUSE, FRANCE

SCENARIO Complex, manual hydraulic system assembly.

WHAT To optimise hydraulic system assembly through the usage of smart tools and Virtual/Augmented Reality.

WHY To evaluate the impact of an adapted AR HMI in terms of performance and error rate for different skilled groups of people and to enable full quality assurance approach and operators performance thanks to traceability.

CESA | MADRID, SPAIN

COMPAÑIA ESPAÑOLA DE SISTEMAS AERONAUTICOS S.A.

SCENARIO Landing gear retraction actuator assembly: Manual deburring operation | Assembly process.

WHAT To incorporate a robot to assist the worker in the deburring operation | To incorporate AR based guidance based on operator's profile as well supporting knowledge sharing.

WHY To increase the quality, efficiency and ergonomics of the deburring process | To reduce operators training time through AR; to reduce time for reviewing documentation; to increase confidence, participation, and internal communication among the personnel.

LAB PILOTS

IK4 ● TEKNIKER | EIBAR, SPAIN
Research Alliance

SCENARIO Collaborative assembly in a fenceless environment.

WHAT To introduce active safety measures supporting Human-Robot collaboration; to support personalized ergonomic adaptation; to provide natural Human-Automation multi-channel interaction; to provide decision support dashboards for quality and maintenance.

WHY To evaluate trust, usability and worker satisfaction (in terms of safety, interaction, ergonomics, assistance).

RWTH AACHEN UNIVERSITY | AACHEN, GERMANY

SCENARIO Final assembly of electric vehicles.

WHAT To incorporate AR based guidance based on operator's profile and to provide the tools required for the assembly by means of an automated tool trolley.

WHY To improve worker satisfaction, to reduce training time, to improve process efficiency; to improve ergonomics; to validate a tool to determine the optimal degree of automation.

HÉROUX-DEVTEK PRODUCTION NEEDS

- **Main characteristics of CESA production (assembly area):**
  - Highly manual
  - High expertise of the workers needed
  - Small batches
  - High variability of the products
  - Wide production ratio (from 4 to 140 per year)
  - Highly restrictive quality requirement
  - Some process have a risk for the health of the workers

- **CESA assembly use case**
  - Retraction actuator of the main landing gear of a single aisle comercial aircraft
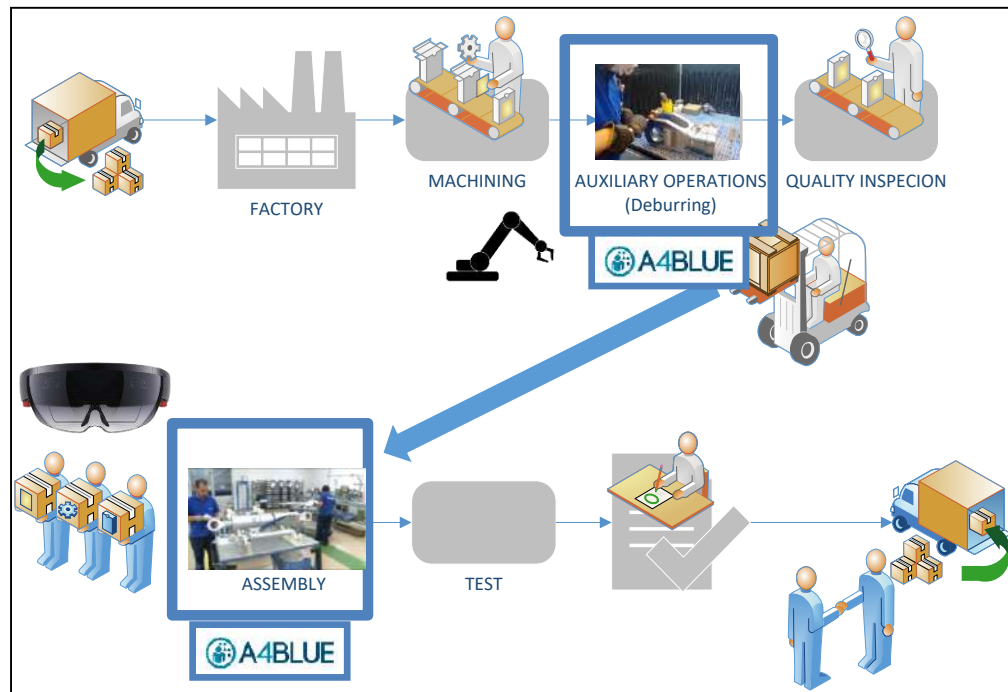 - Around 200 units/per year

DIMENSIONS RETRACTED 1428.8 mm
DIMENSIONS EXTENDED 2092.2 mm
WEIGHT 132.5 Kg
PRESSURE 350 bar

HÉROUX-DEVTEK SPAIN USE CASE

- **RETRACTION ACTUATOR ASSEMBLY PROCESS:**
  1. Auxiliary operation: human-robot collaborative deburring of a titanium part
  2. Main landing gear guided assembly using AR

- **"AS IS" MANUAL DEBURRING PROCESS**
  - The raised particles and shavings that appear when metal blanks are machined are referred to as burrs, and the process by which they are removed is known as deburring.

Titanium
Earth End

STEP 3. SMOOTHING MACHINING MARKS

A4BLUE

- MOTIVATION:
  - Collaborative work
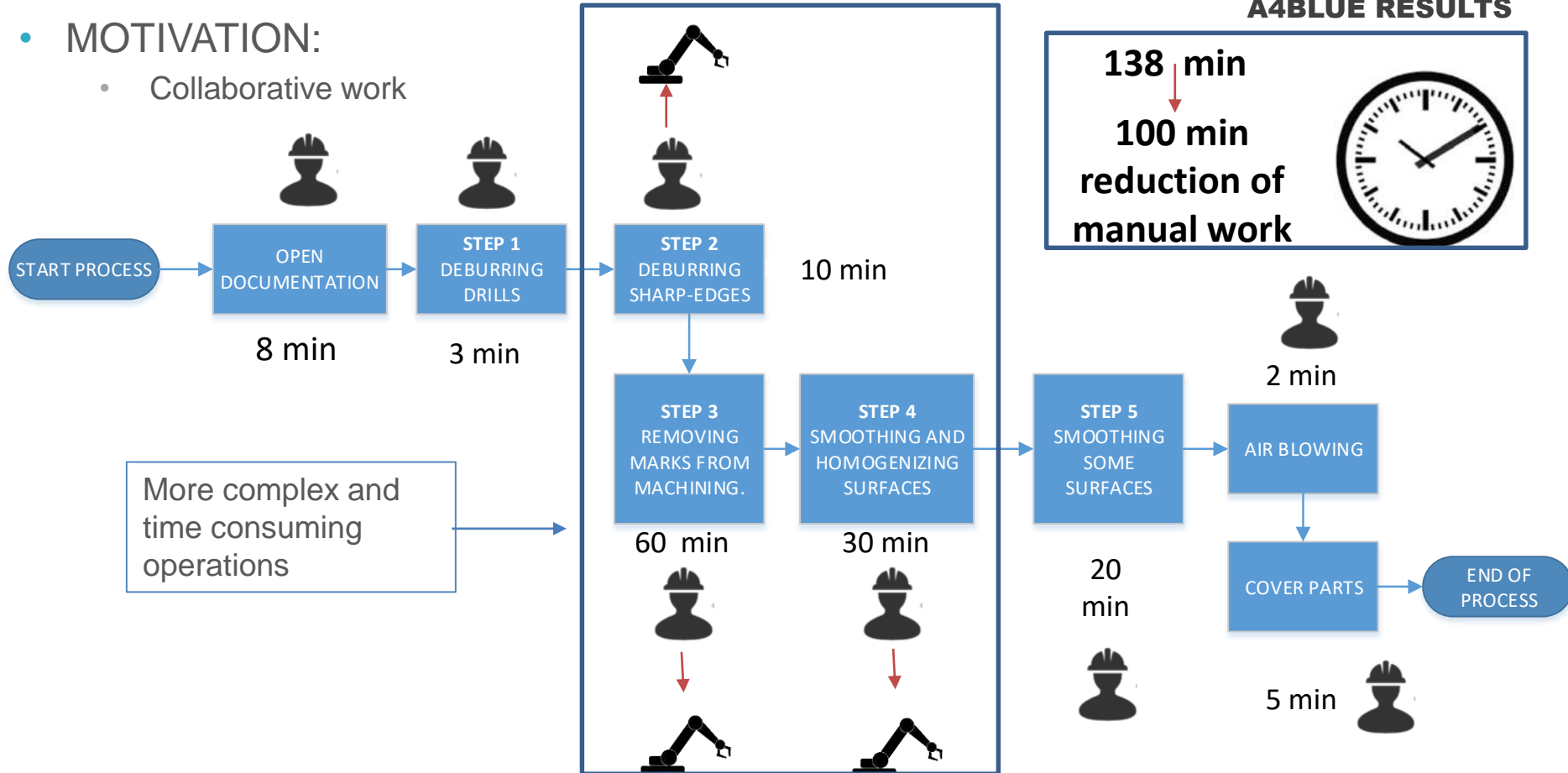
138 min

100 min reduction of manual work

START PROCESS

OPEN DOCUMENTATION

8 min

STEP 1 DEBURRING DRILLS

3 min

STEP 2 DEBURRING SHARP-EDGES

10 min

More complex and time consuming operations

STEP 3 REMOVING MARKS FROM MACHINING.

60 min

STEP 4 SMOOTHING AND HOMOGENIZING SURFACES

30 min

STEP 5 SMOOTHING SOME SURFACES

20 min

AIR BLOWING

2 min

COVER PARTS

END OF PROCESS

5 min

A4BLUE

- HUMAN-ROBOT COLLABORATIVE DEBURRING OF A TITANIUM EARTH END

https://vimeo.com/334929783

• BENEFITS

- **Improves ergonomic** and safety conditions of operators→ less exhausting part, avoid breathing metal chips

- **Increases productivity**, as operators can use this time in a more effective way→ 100 min reduction of manual work

- **Less training** needed → level of expertise required is less demanding by reducing dependence on manual work

- **Quality** has been maintained at the same good level

- It **adapts** to the operators different profiles

- **Flexibility** as new parts can be programmed to be deburred by the robot
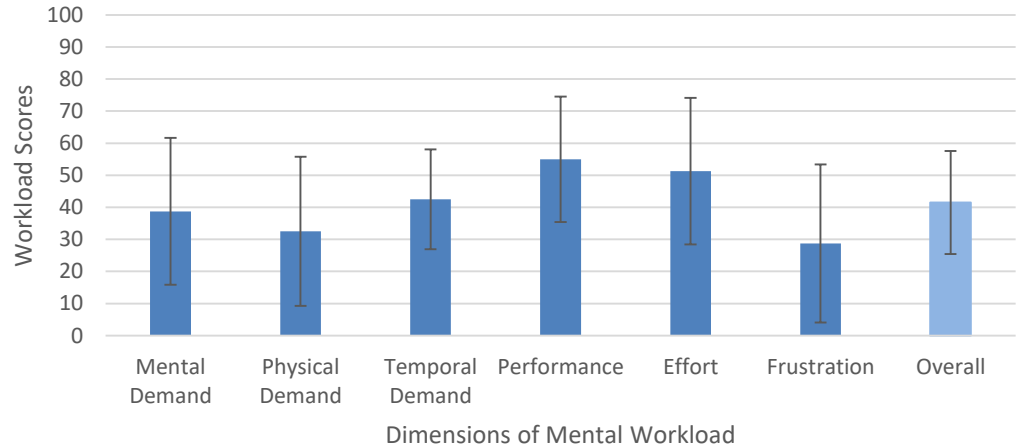

- Deburring robot is fully implemented in serial production

DEBURRING APPLICATION SCENARIO USABILITY ASSESSMENT

Cranfield University

- 4 male participants completed the usability, and mental workload surveys.
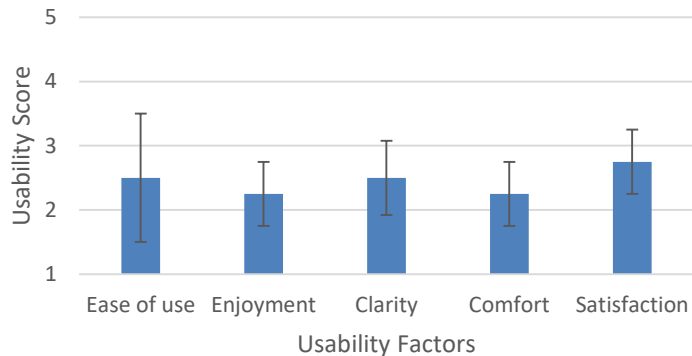
Good/central usability scores

Central Mental Workload: neither overloading nor under-loading

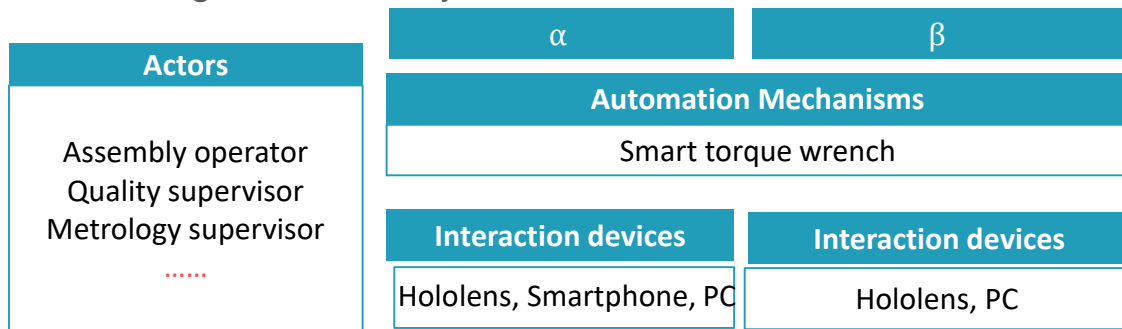# DEBURRING APPLICATION SCENARIO SATISFACTION ASSESSMENT

Cranfield University

Trust				
Major Component	Individual Statement	Averaged Scores	Summed Scores	Total Trust Score
Robots motion and pick-up speed	The way the robot moved made me uncomfortable	4 (0.5)	8.3	39.8
	The speed at which the gripper picked up and released the components made me uneasy	4.3 (0.5)		
Safe co-operation	I felt safe interacting with the robot	3.8 (1.5)	15.4	
	The size of the robot did not intimidate me	4.3 (0.5)		
	I was comfortable the robot would not hurt me	4.5 (0.58)		
	I trusted that the robot was safe to cooperate with	2.8 (2.06)		
Robot and gripper reliability	I felt I could rely on the robot to do what it was supposed to do	3.8 (0.96)	16.1	
	I knew the gripper would not drop the components	4 (0)		
	The robot gripper did not look reliable	4 (0)		
	The gripper seemed like it could be trusted	4.3 (0.5)		

- Good trust levels (25 to 50).
- Item: "I trusted that the robot was safe to cooperate with" low score, concerning and requires addressing.
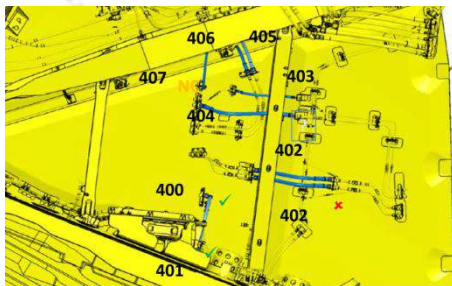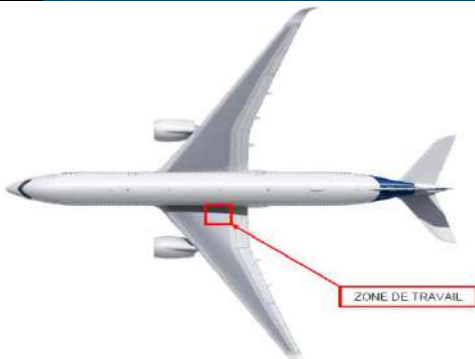
Airbus use case scenario: Overview

Scenario: Towards a more optimized hydraulic system assembly on the A350 Over Wing Panel comprising various sets of operations including a lot of different parts to be installed in constraint positions through Automation and Virtual/Augmented Reality

Actors	α	β
	Automation Mechanisms	
Assembly operator	Smart torque wrench	
Quality supervisor		
Metrology supervisor	**Interaction devices**	**Interaction devices**
....	Hololens, Smartphone, PC	Hololens, PC

Main motivation:

1. To evaluate and measure the impact of an **adapted AR HMI** in term of **performance** and **error rate** on the assembly execution for different skilled groups of people.
2. Enable **real-time monitoring** and **synchronize automatically information** among different types of resources (H2M, H2H, M2M, M2H)
3. Enable **Full Quality Assurance** approach and Operators performance thanks to **traceability**

https://vimeo.com/337518814

From the training …. to the production assembly   … to the quality inspection

Trials set up

Protocol in two parts done with 7 operators:
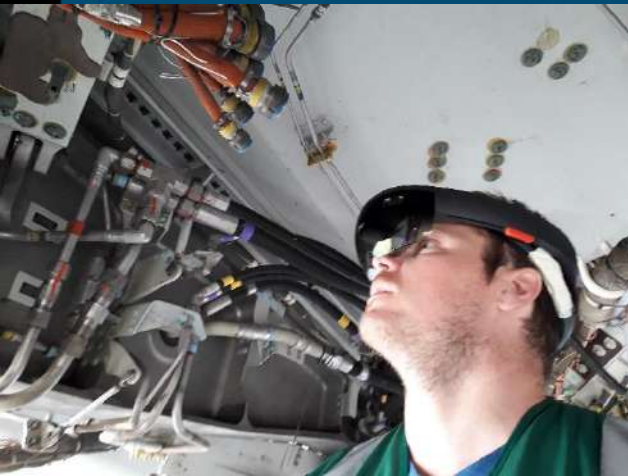
Mockup training

- Brief explanation and consent
- Explanation of the smartool use
- Explanation of the hololens gestures
- Brief on mockup purpose for learning A4BLUE tooling and pipe assembly as a success criteria
- Mockup trial & survey

Over Wing Panel assembly

- Over Wing Panel trial explanation (Qcode, calibration, …) emphasize on tool and holo connection
- Assembly of, at least, one union of a pipe
- Survey on OWP trial

1 A350 MSN3 Test Aircraft booking
1 lift Toucan licence & booking
7 Operators slot (2h)
Intervention card signed for each day of trial
A4BLUE IT platform set up:
3 laptops, 1 WiFi app, 4 hololens (1 broken)
2 torque wrenches, 2 smartphones, 1 mockup and ~1 kilometer of miscellaneous cables ☺

Operator training , assembly and administrative tasks

TRAINING

- Alpha mockup used
- Train on the smartool'use
- Learn the hololens gestures

OWP ASSEMBLY

- Automatic synchronization
- Support to feed the Operator's report

User

Tool

Job

ADMINISTRATIVE TASKS

- Real-time monitoring
- Full Quality Assurance and traceability

SOI PROCESS FOLLOW UP

JobOrder	OperationDescription
JO_soi001	Preparer serrage au...
JO_soi001	Preparer serrage au...
JO_soi001	Preparer serrage eu...
JO_soi001	Serrer le raccord gauche au coup... soi.001-Task_03.04.01	Finished
JO_soi001	Serrer le raccord gauche au coup... soi.001-Task_05.04.01	Finished
JO_soi001	Serrer le raccord gauche au coup... soi.001-Task_01.04.01	Finished
JO_soi001	V<<3=<a9=nfier tous les tuyaux soi.001-Task_000.02	Finished
		Pending
		Pending
		Pending

2019-09-09T10:14:17Z
2019-09-09T10:14:37Z
2019-07-17T08:32:48Z
2019-07-18T12:19:28Z
2019-07-17T08:32:48Z
2019-07-17T08:32:13Z

PROCESSPARAMETERS FOLLOW UP

JobOrder	Operati...	Operati...	OperatorIdentifier	Process...	ToolIdentifier	RealValue	TargetValue	Deviation
JO_soi001	Prepar...	soi.001...	1.00	http://...	1731M005	51.30	50.50	-0.40
JO_soi001	Prepar...	soi.001...	1.00	http://...	1731M005	24.15	21.50	-0.57
JO_soi001	Prepar...	soi.001...	1.00	http://...	1731M005	44.95	21.50	-5.04

Some words from operators during the trials

« It is exactly that ! »
Speaking about the torque value set to the torque wrench

« It is great to participate to these trials, it changes from our daily life and
it will come to us in a future ! »
Waiting in the elevator when job order was downloaded

« Excellent ! »
When the torque wrench was automatically set to the release point

« Fun & Cool »
Enjoying the use of the smartool and the holo for the mockup and on OWP

« No don't worry, it's worth spending time waiting, it's really interesting these new technologies, it will improve a lot things even if it is still research but it's good that it comes here
After one hour of technical troubles with network connection, IT troubles, …
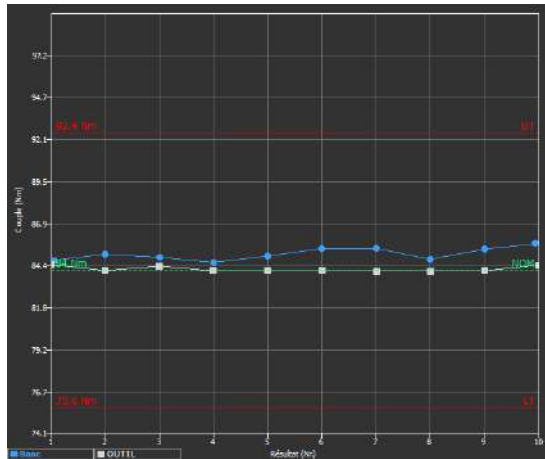
Heartbeat of th SmartTool DynaSam 4.0
from the Airbus metrology bench

10 measurements at 84 Nm
------ : authorized tolerency on the Aircraft
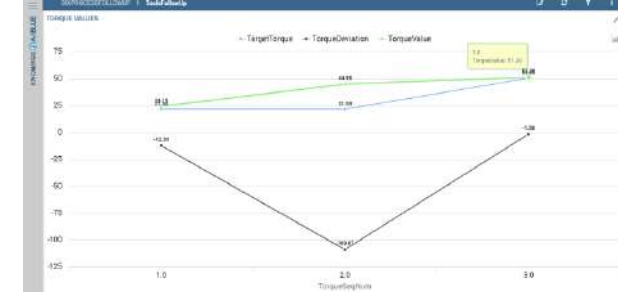
Use case 1: measure the deviation on a tool to a
dedicated torque value in time

Use case 2: detect & alert &
block the tool in case of
malfunction, test done on
fall down detection.
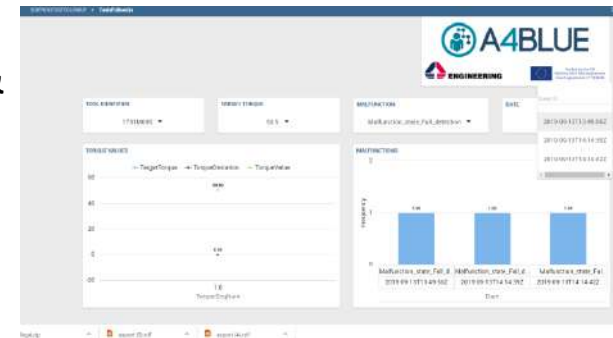
Airbus use case scenario: Challenges summary success

| Challenge		A4BLUE Vision
CH1.1- Adapted on the job guidance	Human, process & ✓ context variability	A4BLUE should provide on the job guidance adapted to both the specific worker and operation involved. Both the way the information is displayed to the workers and the AR device to display such information should be considered.
CH1.2- Adaptation of the tools involved in the assembly process	Process variability ✓	A4BLUE should support the automatic adaptation of the parameters of the tools involved in the assembly process considering both the operation being performed and the related standard operating instructions.
CH1.3. Decision support	Process variability ✓	A4BLUE should support the Quality Inspector to secure a full quality assurance approach by making available in-real time the information collected from the smart tools (not available in the current process) during the assembly; avoiding to manually control the executed task, ease the error detection and then correction, measure the realization time to ensure time and quality delivery.

+ (2 more regarding metrology)

- **RETRACTION ACTUATOR GUIDED ASSEMBLY USING AR**

- MOTIVATION:
  - **Reduce the amount of time** spent by the operator looking for information
  - **Reduce training** times
  - Easy way to **share tips** between workers: Lessons learnt data base
  - **Increase confidence,** participation, and internal communication among the personnel of the organization
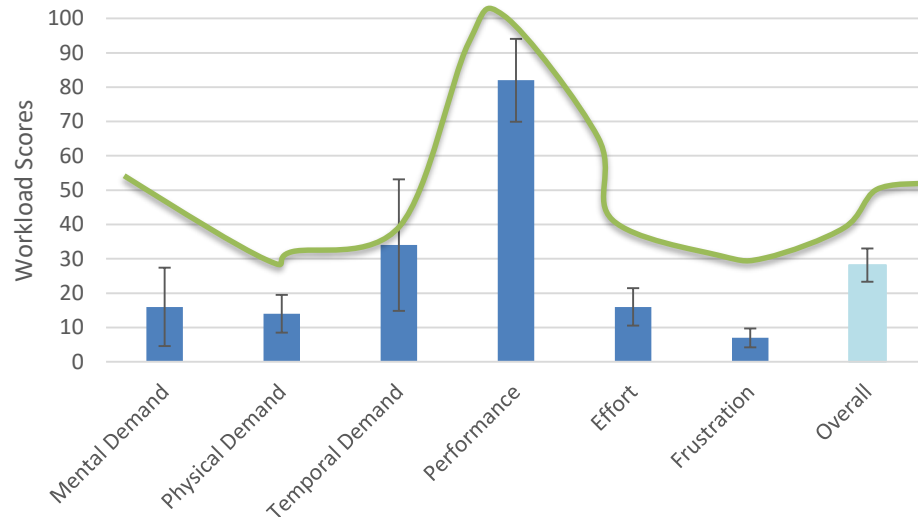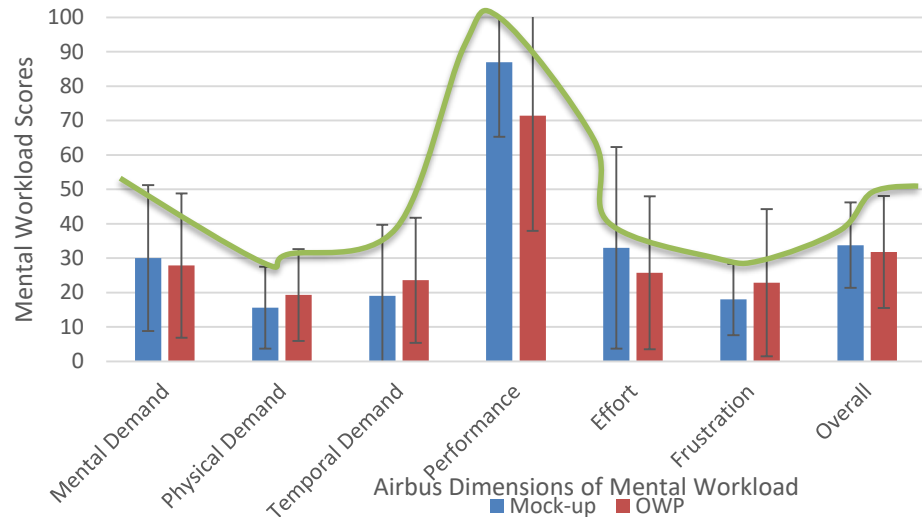 - Avoid **quality scapes**

Airbus & HÉROUX-DEVTEK Usability Assessment
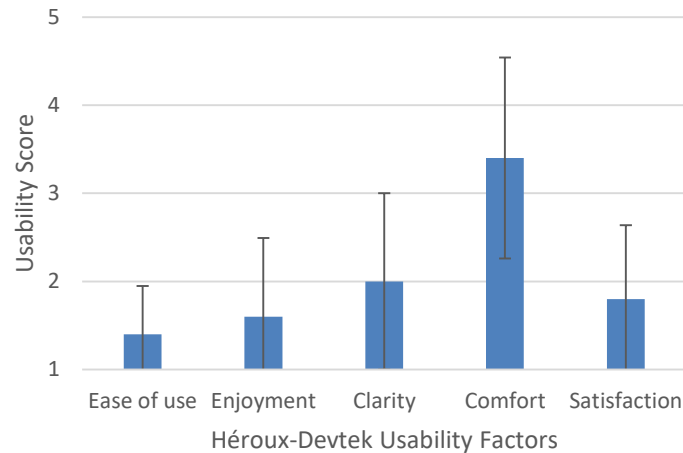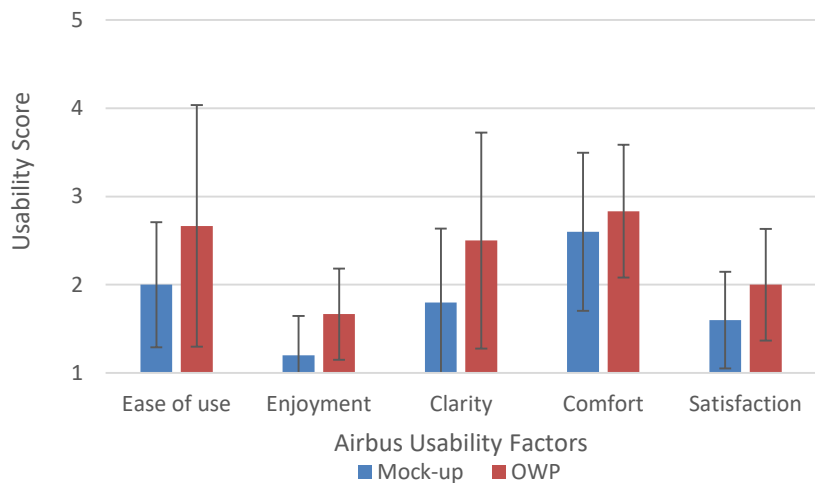
In both business cases good usability scores with a poor comfort scores for both
In Airbus, Mock-up has better usability than the OWP results.

Airbus & HÉROUX-DEVTEK Mental Workload Assessment

Airbus Dimensions of Mental Workload
Mock-up ■ OWP ■

Héroux-Devtek Dimensions of Mental Workload

Despite their differences in their jobs & companies, operators' scores follow the same trends.

Low mental workload scores with high performance scores indicates a level of under-loading potentially due to familiarity with the task.

Airbus & HÉROUX-DEVTEK Share Benefits on A4BLUE

- Easy and **friendly interface**→ helpful assembly animations and clear instructions
- **Adaptable** to different experience profiles
- **Training**→ extra guidance for less experience workers
- Increases **traceability**→ everything can be recorded, reported, including final signature of the tasks


- **Improve productivity**→ reduce time used by the operator to look for information
  - Only show information needed by the operator as each precise moment
- Easy way for the **operators to share tips** and comments

- **Automatic synchronization** with the torque wrench
- Real-time **monitoring**

http://a4blue.eu/

Adaptive Automation in Assembly
For BLUE collar workers satisfaction in Evolvable context
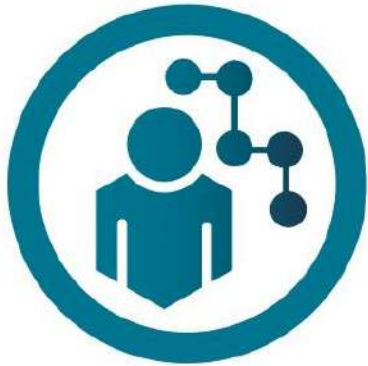
Laure.parigot@airbus.com
MARIA.OTERO@herouxdevtek.com

THANK YOU