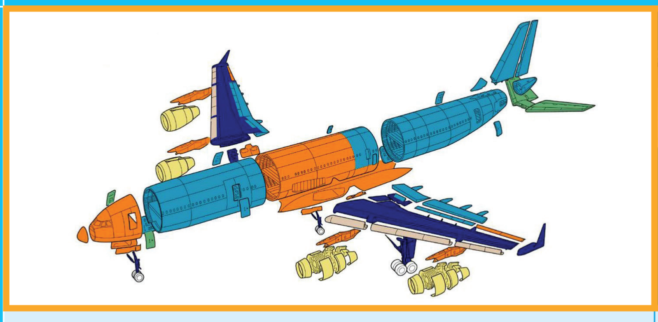
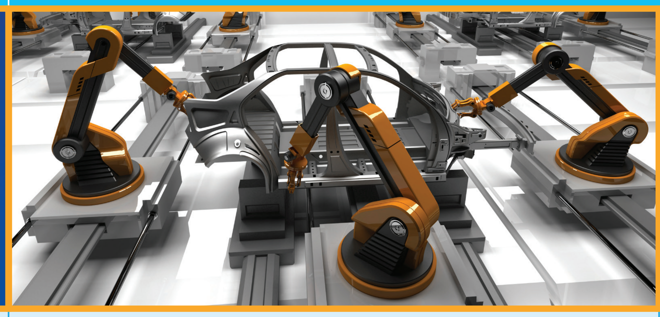
Large Volume Applications

Metrology solutions needed to support research and Industry 4.0

	AEROSPACE		AUTOMOTIVE & DIGITAL INDUSTRY 4.0		BIG SCIENCE
					
END USER NEED AND SOA	**International traceability** **Need:** calibrate/verify 100s of trackers across 5 countries **Need:** multiple point measurement simultaneously **SOA:** requires intrinsic interferometer **SOA:** single point at a time	**Clean Skies: Laminar Flow Wing, aircraft overall weight loss** **Need:** Improved jig and manufacturing accuracy to 100 µm full wing accuracy, traceable across countries **SOA:** 400 µm	**Industry 4.0, Energy production, Digital Factory, DESC** **Need:** Digital-ready tools work together **Need:** Error map & verify large tools in production line, cheaply to < 100 µm **SOA:** Non cooperative software **SOA:** 200 µm or expensive trackers	**Precision engineering industries making high value or critical components** **Need:** accuracy despite air T gradients, **Need:** 100 µm in 15 °C to 30 °C factory, **SOA:** 500 µm without compensation 200 µm using slow photogrammetry, single point air sensor	**Next generation science infrastructure** **Need:** 10 µm accuracy every 200 m along 25 km tunnel or beams won't collide **SOA:** 100 µm to 300 µm
IMPACT MATRIX AND BEYOND SOA	FSI: **intrinsically traceable** system, better uncertainty (10^{-7}) from HCN data, multiple points simultaneously	FSI: **50 µm** accuracy, **10 x** better traceability *via* HCN Multilateration telemeter system	*InPlanT*: **5 µm** target, **cheap**, embedded. Multi camera **traceable** photogrammetry. FSI: **50 µm** – reference network and mapping tool.	Spectroscopic and acoustic thermometers, operating to 10^{-7} along the beam; **gradient** measurement Refractive compensating multilateration telemeter system	FSI system **at 50 µm**, novel refractive index compensating telemeters
	Self-organising metrology networks, with unified instrument interfaces controlling autonomous processes with cooperative tasking and AGVs Error map & verify large machine tools in production line with cheap embedded systems Traceable photogrammetry systems for close range robotic part inspection with reliable uncertainties – metrology enablers for digitisation of LV manufacturing FSI, new telemeters, improved refractive index, multi-scale photogrammetry: demonstrated in automotive/aerospace/Industry 4.0 demonstrator scenario				Refractive index compensated telemeter, FSI system
	3D temperature network: 10x reduction in refractive index enabling all optical tools to achieve required accuracy; portable refractive compensated length references for traceability				
	New metrology capability at partners, exploits LUMINAR IP further, novel uses foreseen by several stakeholders, new IP portfolio, stakeholders identified and actively engaged in bid writing and project				
	Delivers requested SRT impacts: standards inputs, knowledge transfer to aerospace & automotive; assures international traceability; assists early stage NMI members setting up labs, developing skills				

WP3 - High accuracy refractive index

1. **Spectroscopic thermometer prototype**
   High accuracy, 5 m to 50 m, based on molecular oxygen
2. **Pulse-based acoustic thermometry and refractive index**
   (a) Time of flight systems: 2 m and 50 m variants
   (b) Continuous wave system, investigation of 3D temperature gradients
3. **Comparison of systems in lab and real-world**
   3D index and reference length for LVM

WP2 - Novel techniques for medium/ large volumes

(i-a) NMI-class 3D in-line inspection system
Robot compatible, with intelligent data processing
Industrial case study of aerospace/automotive part measurements
(i-b) Industrial multi-camera for traceable 3D
Providing absolute 3D coordinates
(ii-a) Air index compensated multilateration 3D prototype
Designed for accurate part fiducialisation
(ii-b) Cheap multi-camera system for 3D in very large volumes

"We believe that the technologies planned for development in this EMPIR project have a high chance of success … and that through their delivery, the project consortium will significantly advance the SOA of Large Volume Metrology. In particular we foresee several potential application areas for the technologies being developed".

5 signatories representing Airbus Engineering, Business Development, Laboratories & Test Centres, Data Capture, Structures (UK and France)

JRP Demonstrators

Intercomparison on refractive index

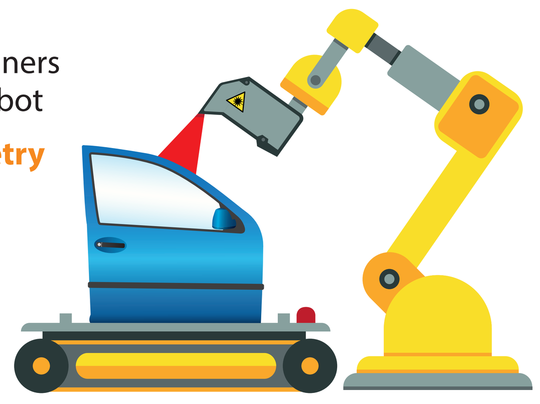
Part is inspected

Inspection is either done with free-form scanners (preferred) or tactile sensors attached to a robot

Robot is referenced either by photogrammetry or FSI depending on required uncertainty

Measurement process is implemented to be regarded as traceable

Further navigation is decided on inspection result



AGV navigates part to inspection

AGV tracking must have maximum availability within possible travelling range

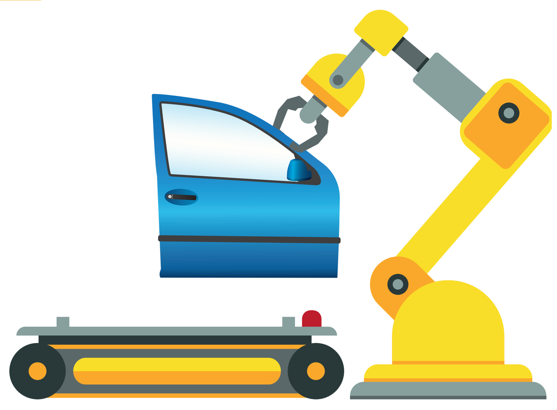
Digital model of the process and data from low cost positioning of resources (e. g. photogrammetry) allows calculation of optimal schedule and route to inspection

If the AGV tracking system fails, it can either be taken over by another available positioning system or navigation continues by means of model-based prediction

Part loaded onto AGV

Robot is tracked by Photogrammetry

AGV tracking and Photogrammetry are referenced to each other for seamless transition

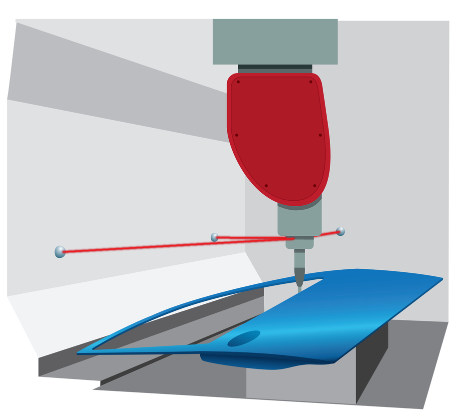


In situ machine tool metrology

Embedded targets remain in machine, with laser optics in wrist.

Automated error mapping.

Online performance evaluation pre-, past- manufacture of parts.



Intercomparison on photogrammetry systems

WP1 – Improved FSI metrology

1. **Develop multiple independent measuring system**
   Linear and saturated absorption
   HCN cells at different pressures
   Improved peak fitting
2. **Comparison of cells and system**
   Absolute and relative spectroscopy
   Saturated spectroscopy
   Open access HCN data
   Integrate into FSI system

WP4 - Process modelling and unified interfacing

1. **Metrology oriented process and device models**
   Cooperative network of instruments
2. **Unified interfacing of LVM devices**
   Open access interface, easily integrated into networks
3. **Real-world auto/aero/digital Factory 4.0 integrated demonstrator system**
   AGV, laser trackers, refractive-compensated telemeters, photogrammetry, FSI
   All under a unified control interface, with cooperative tasking
   Automated trans machine/trans robot transfer

WP5 - Traceable large machine tool metrology

1. **Improved optical targets**
2. **Low cost system embedded in large machine tool**
3. **Integrated with machine controller**
   Allows ongoing checks during production
4. **Demonstrated on Fidia machine and another at RWTH end of project demonstrator**

DISSEMINATION		IMPACT		
Exploitation	**Knowledge transfer**	**Financial**	**Social**	**Environmental**
• IP uptake by partners – Fidia, MapVision • Licensing to metrology companies: – e.g. Renishaw, Hexagon, Leica • IP list and exploitation plan • NMI services & consultancy • Open access HCN data via MeP • Unified instrument interface for Industry 4.0 metrology network	• Stakeholder committee • JRP open website and sci-social media • 12+ major industrial LVM conferences • 2+ technical & standards committees • 5+ open access journal papers • 2 trade articles (already one invite) • NPL Dimensional Training Framework • Training sessions at CMSC, 3DMC • Major industrial demonstrator setup • Industrial workshop at end of project	• Critical to Laminar Flow Wing: – Safeguards €2.3 trillion 2030 orders whilst complying with 2020 regulations; • Saves money on high value components – €10k per day engine depreciation – Reduced scrappage via in line self-checking of large machine tools	• Enables LHC successor to work (science jobs, new knowledge) • Enables improved beam therapies for oncology • Maintains EU advanced manufacturing advantage over USA and Asia: – €498m EU engineering turnover, 3.25m jobs – EU has 36 % market share machine tools worldwide – 4.2 million EU jobs in aviation	• Benefits from estimated 100 kg lower aircraft weight from JRP outputs, per aircraft: – 38.5 tonnes less CO_2 p.a. – 1.4 M litres of fuel saved p.a. • Enables manufacturing of small modular nuclear reactors (reducing CO_2, NO_x) • Enables science for >breakeven fusion reactors

"I believe this project represents some of the most exciting developments in large volume metrology in recent years. . . . It is also exciting that this development may create applications of metrology that have not at present been possible or even envisaged." *INSPHERE*

"… the addressed objectives in the proposed JRP in the field of LVM are challenging and fit perfectly with what it is expected for the industry 4.0" *Symop*

"We believe that the work proposed under the LaVA project could lead to the development of game-changing new products with a significant impact on large scale metrology and high value manufacturing operations in aerospace, automotive, power generation and others." *Renishaw*

"The project consortium will significantly advance the state of the art of Large Volume Metrology. In particular we foresee several potential application areas for the technologies being developed in the project." *Starrag Technology*