SMART Production System with Full Digitalization for Assembly and Inspection in Concept of Industry 4.0

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Abstract. The paper describes design of smart production system with full digitalization for requirements of Industry 4.0. The system consists of three level of technologies: production technologies, inspection subsystem and digitalization software system. Production technologies creates parts for assembly: small CNC, Rapid prototyping device and standardized parts storage with assisted assembly process by collaborative robot combined with mixed reality device. This system provides assisted assembly work cell. Inspection subsystems consist of RFID readers with passive tags, vision system with basic 3D inspection, multi-spectrum light for error detection and 3D profilometer precise measuring. Digitalization software is represented as Digital Twin model implemented to server, which uses OPC communication for data transfer from production system to Cloud Platform with additional data from IoT devices.

Keywords: SMART manufacturing · Inspection · Digitalization · RFID · Vision systems · Cloud platforms

1 Introduction to Smart Production Systems

SMART production system automatizes operation with some level of adaptability during whole manufacturing and assembly process. The additional task is data digitalization from every operation, production, inspection, and assembly. The other research in area of smart production was published in these articles [1–8]. The current technology trend is implementation of contactless technologies for inspection especially vision systems and RFID devices. Some research published in area of vision systems aimed to object recognition by artificial neural networks [9–12]. All acquired data during digitalization are used for creating digital twin and some paper solving problems in this area [13]. Extra data after production can be acquired during product lifecycle from customer by IoT devices combined with MEMS sensors. Some articles published in area of IoT and MEMS are [14, 15]. Principle scheme of experimental SMART production system with

D. Perakovic and L. Knapcikova (Eds.): FABULOUS 2021, LNICST 382, pp. 181–192, 2021.
https://doi.org/10.1007/978-3-030-78459-1_13

connection to digital data processing developed in our department for research and teach activities is shown on the Fig. 1.

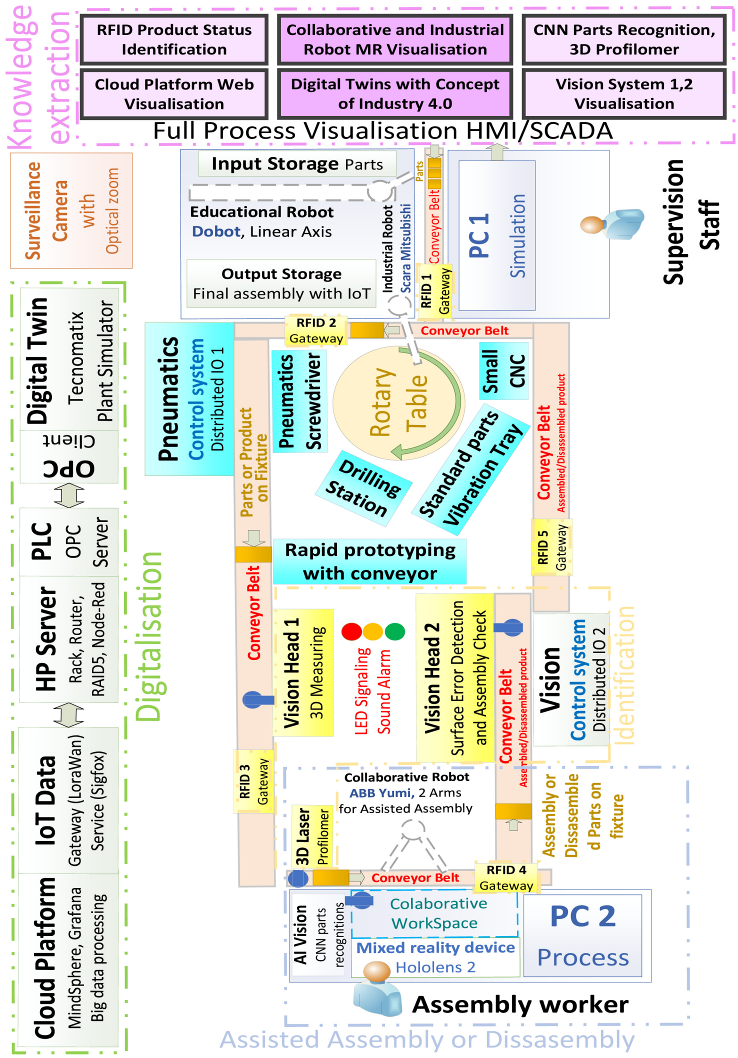

Fig. 1. Proposal flowchart diagram of smart production system with full digitalization.

All used technologies need some digital feedback to ensure self-diagnostics with some level of adaptability and automatized prediction of future status for operation as SMART production system. It can be defined three groups of technologies, which need digitalization. The first group is manufacturing technologies and second group inspection devices and last third group are control systems and Data processing. All data must be accumulated in one place (Cloud Platform) for knowledge extraction and complex decision plan. Detailed description of production technologies and its parameters with possibilities of data digitalization are shown the list of technologies used for inspection of experimental product in production system is shown in Table 1.

Table 1. Table of used technologies in production parts of system.

Production system	Used product	Digitalization possibilities
Pneumatics screwdriver	*Schneider DRS 1000*	Only position sensors
Vibratory feeder bowl	*DOXX*	Binary/speed control
Small CNC	-	Ehternet
Rapid prototyping	*Conveyor*	Ethernet
Industrial SCARA robot	*Mitsubishi RH6-FRH*	Profinet
Collaborative robot	*ABB Yumi*	Profinet

The list of technologies used for part production, manipulation and assembly process is shown in the list of technologies used for inspection of experimental product in production system is shown in Table 1.

The list of technologies used for inspection of experimental product in production system is shown in Table 2.

Table 2. Table of used technologies for inspection process.

Inspection technology	Used product	Digitalized data
Vision system 1	*Keyence CV-X 3D Measurements*	Parts shape errors
Vision system 2	*Keyence CV-X Multispectral*	Assembly check
3D profilometer	*Keyence LJ-X 3D Measurements*	Dimension check
RFID low frequency	*Siemens RF200*	Standard parts ID
RFID high frequency	*Siemens RF300*	Manufactured parts ID
RFID ultra high frequency	*Siemens RF600*	Fixture ID

Table 3. Table of used technologies for system control and data storage.

Control systems and data processing	Used product	Digitalized data
PLC	*Siemens S7-1500*	OPC Server/Profinet
SCADA	*Siemens TP-1500*	Profinet
Server	*HP Primergy*	OPC client

The list of technologies used as control system for all parts of production system and data backup is shown in The list of technologies used for inspection of experimental product in production system is shown in Table 3.

2 Prototype of SMART System

The design of experimental SMART production system consists of three stages. The first preparation of 3D models of all physical devices (manufacturing devices, inspection technologies and control and data collection system) connected to communication chain. The second is realisation of protype SMART manufacturing system and last transformation all 3D models to digital twin and real time connection to all real processes.

2.1 3D Design Model and Experimental Prototype

The production system was designed in 3D software Autodesk Inventor before establishment to laboratory, the first idea is shown on the Fig. 2.

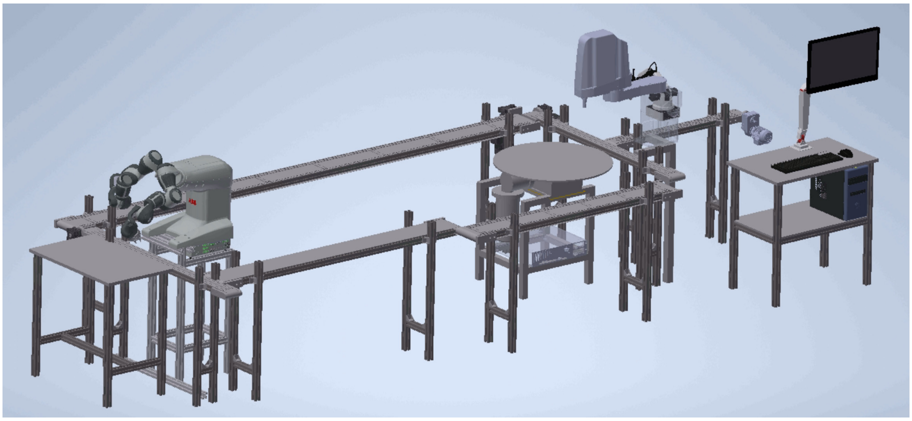

Fig. 2. Autodesk Inventor 3D model of production system before real installation.

Realized experimental prototype of SMART production system established in laboratory is shown on the Fig. 3.

2.2 Cooperative Assembly Robot and Experimental Product

The main workplace is montage cell with assisted assembly of the product on the fixture. Collaboration with robot is realized by mixed reality device Hololens 2, which can detect worker hand and part position in assembled assembly. Collaborative robot detect parts by integrated camera and for positioning uses separate grippers and vacuums.

The collaborative robot and disassembled product are shown on the Fig. 4.

The used mixed reality device Microsoft Hololens 2 and the simulation of assembly process with help of mixed reality device is shown on the Fig. 5.

Fig. 3. Current prototype status of experimental production system installed in our department.

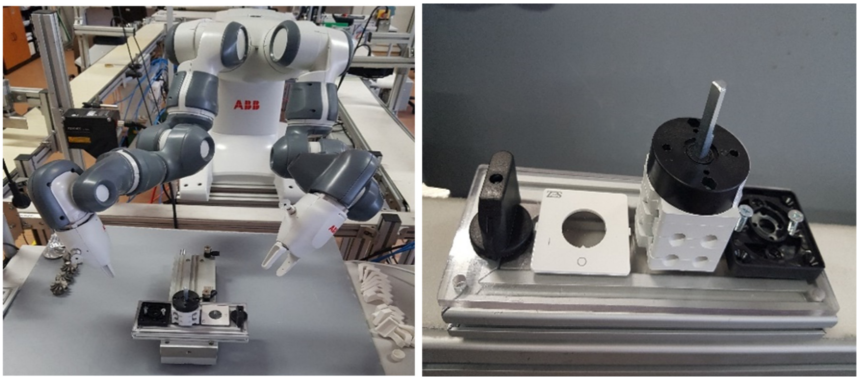

Fig. 4. Collaborative robot from ABB Yumi (left), fixture with assembled product (right).

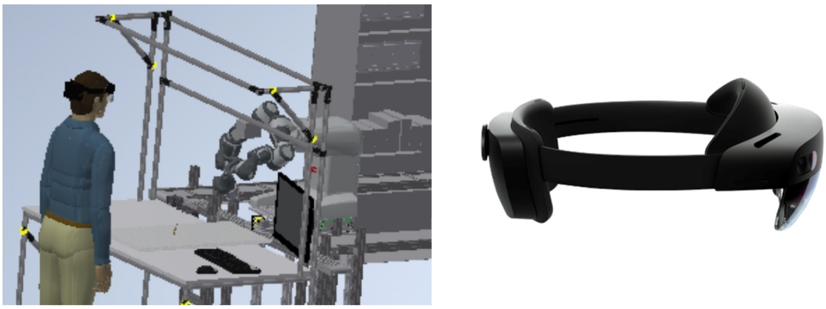

Fig. 5. Mixed reality device Microsoft Hololens 2 (left), Simulation of assembly process with assisted assembly by collaborative robot (right).

2.3 Inspection Technologies Vision Systems and 3D Profilometer

Inspection technologies consists of vision system and RFID readers. Vision systems check input parts quality and output assembly surface errors. 3D profilometer check dimension of the parts before assembly process. RFID systems localize assembly and parts during production process by RFID tags placed on parts, assembly, and fixture.

Inspection devices integrated to smart production system are shown on the Fig. 6.

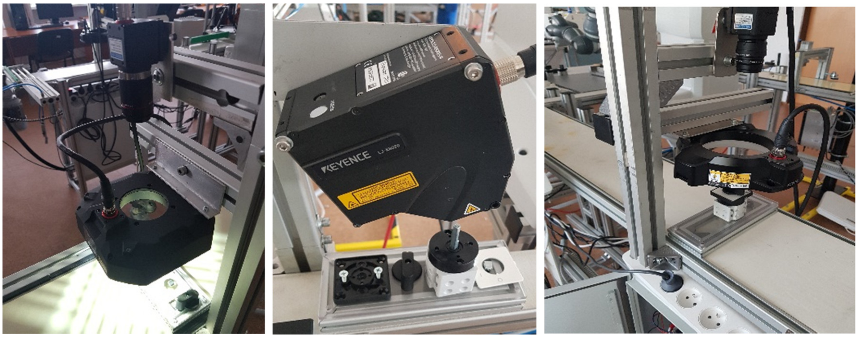

Fig. 6. 3D vision camera system with basic parts check (left), Multispectral vision system for surface error detection (middle), 3D profilometer for parts dimension check (right).

2.4 Inspection Technologies by RFID Readers and Tags

SMART manufacturing system integrates three different types of RFID technologies:

- RFID with LF technology, Siemens RF200
- RFID with HF technology, Siemens RF300
- RFID with UHF technology, Siemens RF600

RFID with UHF frequencies is used for fixture identification in conveyor belt. It was used two RFID readers with two external antennas. The fixtures can be identified in four places before every production operation during movement in conveyor belt.

LF and HF RFID technologies are used for part identification for bigger parts manufactured parts (plastic parts) and for small, standardized parts.

The example of implementation UHF RFID tag in production system is shown on the Fig. 7.

2.5 Control System and Control Software

Electric distribution box with control system based on PLC have separate converter for motor for each conveyor to independent speed control. Two types of PLC are used: Industrial PLC and Software PLC as backup system. Inside structure of distribution box is shown on the Fig. 8.

Schematics of all control and inspection technologies connected to one Profinet networks is show on the Fig. 9.

Fig. 7. Example of RFID system based on UHF technology

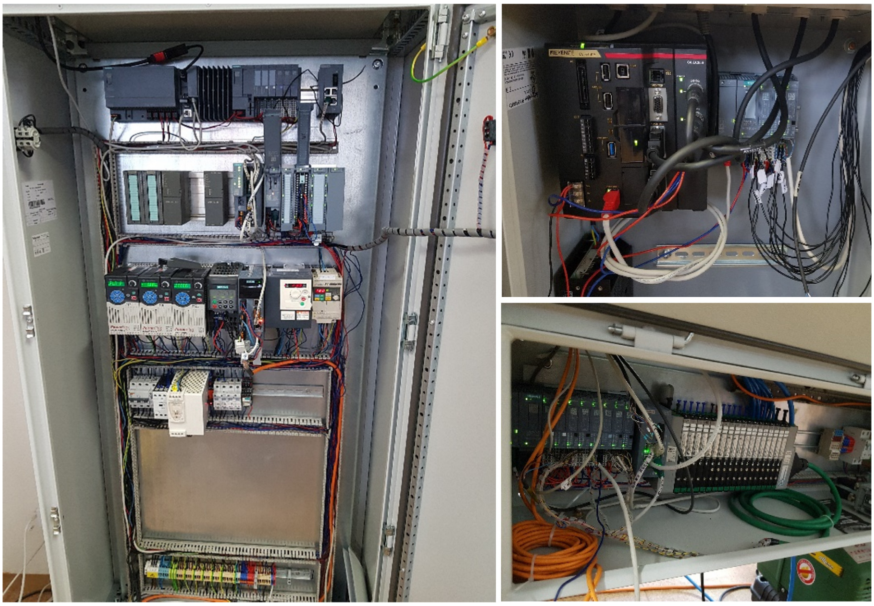

Fig. 8. Current prototype status of experimental production system installed in our department.

2.6 Networking and Communication Systems

To arrange reliable communication which is necessary for real-time data synchronisation to digital twin it must be designed networking structure with optimal bandwidth.

Design of networking structure for SMART production system with optimal backbone is shown on the Fig. 10.

The main system for data storage in Clouds is based on rack server Fujitsu Primergy. The data backup is realized by server HP Proliant. Data are visualized by six LCD panels for monitoring production process and error localization.

The computing section for data storage, backup and knowledge extraction is shown in the Fig. 11.

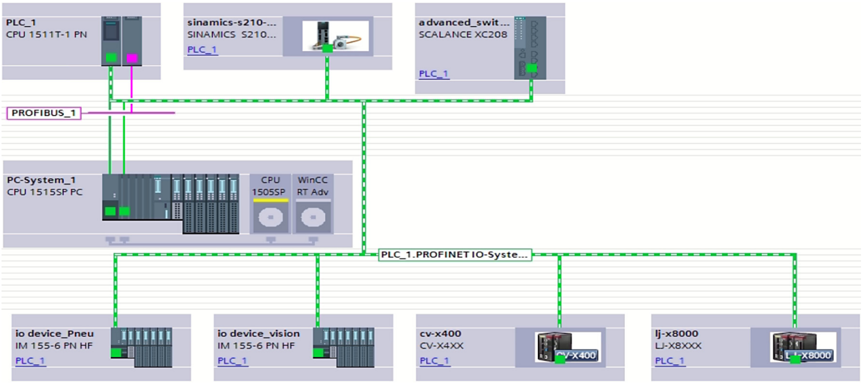

Fig. 9. Current prototype status of experimental production system installed in our department.

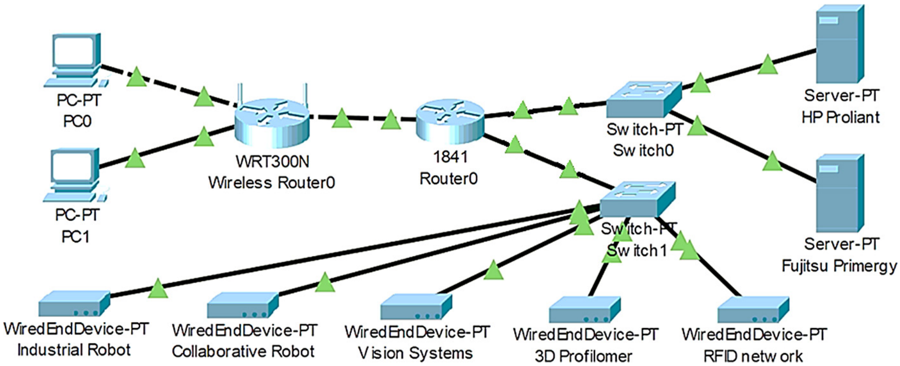

Fig. 10. Design of network backbone for SMART production system.

3 Digital Twin Model

All used technologies were included to simulation software to evaluate timing and optimalisation of production process. It was used Tecnomatix software. This model can be connected to real control system by OPC communication to visualize real-time production process.

2D design of technologies placement from top is shown on the Fig. 12.

Better visualization for operator inspection is possibility of switch 2D model to 3D representation to show error placement or production process delay and is shown on the Fig. 13.

4 Example of Acquired Data

4.1 Inspection System

Inspection systems consist of two industrial vision systems the first with 3D feature acquisition by structural light for product error detection in 2D and 3D and second with

Fig. 11. Rack servers HP Proliant and Fijitsu Primergy (Left), Visualisation of data for monitoring and error localisation (Right).

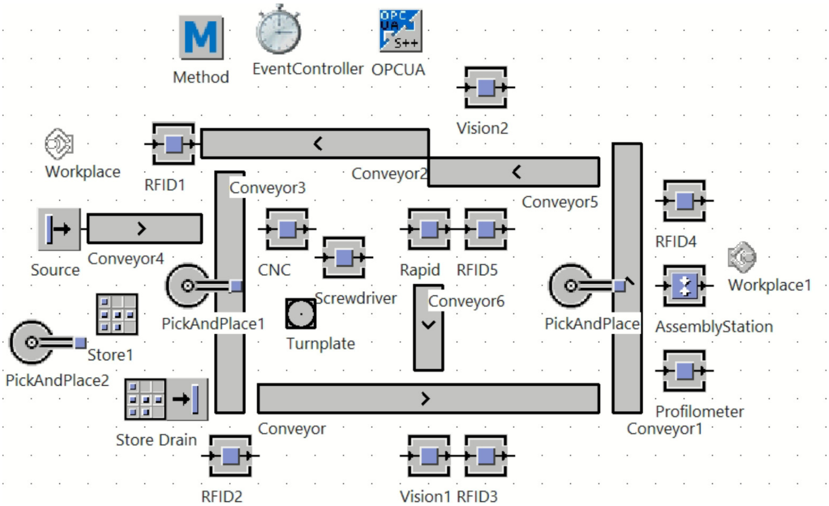

Fig. 12. 2D model of digital twin for realtime optimalisation of SMART production system.

multispectral light system RGB IF and UV for final assembly check as output product inspection. 3D profilometer check dimension of manufactured part in real-time in fixture during movements.

All inspection devices are shown in the Fig. 14.

4.2 Cloud Platform and IoT Devices

Experimental SMART production systems use two different Cloud Platforms for data collection: commercial Mind Sphere with OPC data and open source Grafana with influx

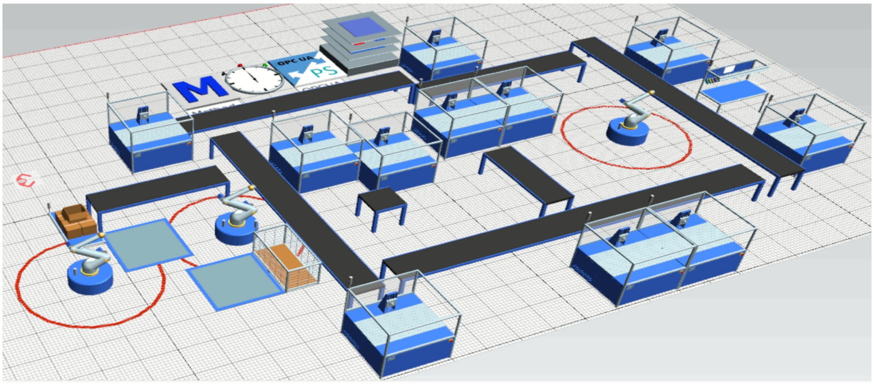

Fig. 13. 3D representation of SMAT production system as digital twin model.

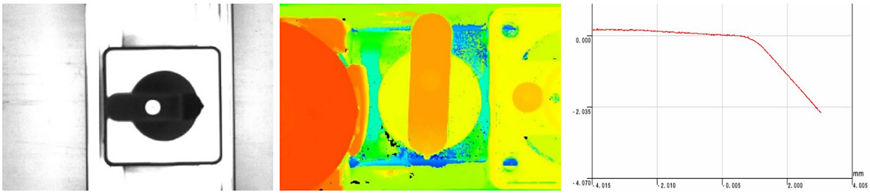

Fig. 14. Graphical output from inspection process: multispectral (left), 3D (middle), profilometer (right).

DB for IoT data collection. The Thinger IO was used for graphical output from simulated IoT device.

Example of data from Mind Sphere Platform and Grafana is shown on the Fig. 15.

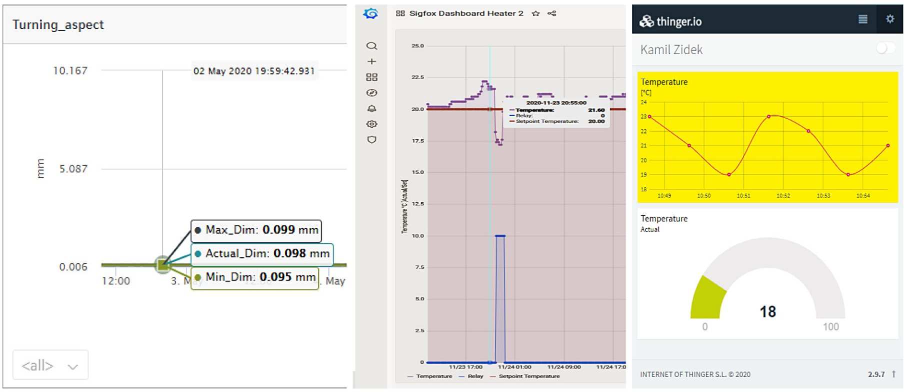

Fig. 15. Mind Sphere Cloud Platform (Left), Grafana with Influx (Middle), Thinger IO output from IoT device (Right).

5 Conclusions and Discussion

The paper present concept of SMART production system with full digitalization based on cutting edge technologies from inspection system and data knowledge extraction by Cloud platform. This concept will be used later for research in maximalization of autonomous tasks and learning activities thru remote access during distance teaching course from web technologies, information and control systems and digital engineering.

Operation staff for whole SMART production system can be minimalized to two people, the first for maintenance, monitoring and engineering and second for manual work like input/output storage service and assisted assembly tasks.

The future works will be implementation of web interface for product customization by user and automated activation of manufacturing, assembly and inspection with personalized data digitalization for each product.

Acknowledgments. This work was supported by the Slovak Research and Development Agency project VEGA 1/0700/20 Identification of Product Defects using Advanced Object Recognition Techniques with Convolutional Neural Networks, KEGA 055TUKE-4/2020 granted by the Ministry of Education, Science, Research and Sport of the Slovak Republic, Slovak Research and Development Agency under the contracts No. APVV-19-0590.

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