Surface Operation by RPAS

RPAS airport operations with use of Airport Moving Map for RPAS Ground Control Station

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***Abstract*— One basic principle underpinning the integration of RPAS in ground operations at airport level, in alignment with ICAO reccomandations is that RPAS have to be treated in a similar manner to manned aircraft while duly considering the specific character of remotely-manned operations. RPAS operations have to be compliant with aviation regulations, and their integration into the ATM system should not impact current airspace user operations and levels of safety. RPAS behavior should therefore be equivalent to manned aviation and should comply with the CNS requirements and ground based airport systems. Single European Sky ATM Research (SESAR) "Solution 03a-09" scope is the integration of RPAS in surface operations investigating ways in which RPAS may be able to use a technical capability or procedural means to comply with ATC instructions during ground operations. This Solution is part of SESAR Project Surface Management Operations (SUMO), that received funding from the SESAR Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement No 734153. This paper gives an overview of gaming validation activity performed by ENAV S.p.A and his Linked Third Parties (Techno Sky, NAIS, IDS) in Napoli Capodichino Airport Center with participation of Air Traffic Controllers, RPAS pilots, RPAS experts, Safety and Human Factor experts. During the gaming exercise, participants focused on surface operations by drones. Specific use cases related to "taxi-in" and "taxi-out" operations in both nominal and contingency situations (loss of command and control, loss of communication) were assessed based on the Taranto Grottaglie Airport environment. This paper gives special attention to the use of a dedicated interactive Airport Moving Map for RPAS Ground Control Station (GCS) and analyzes the impact on operations and actors involved in terms of Human Factor and Safety KPAs.**

Airport; Air Traffic Maangement; Drone; RPAS; SESAR; surface operations

I. INTRODUCTION

Until recently, Remotely Piloted Aircraft Systems (RPAS) have been used mainly in support of military and national security operations. However, RPAS operators are now seeking freedom of access also at airport level leading to interactions with the wider ATM system . RPAS come in a variety of shapes and sizes, and fulfill many diverse capabilities. They range in weight from a few grams to several tons, some RPAS fly at slow speeds, while others are capable of very high speed and some can remain airborne for several days.

Accepting a large number of RPAS into the ATM system poses many challenges and, for the R&D activities of SESAR, RPAS ground operations are of special interest. Their speed, maneuverability, other performance characteristics, together with their avionic system equipage may differ substantially from conventional aircraft. Experience of RPAS ground operations and their interaction with the ATM system to date indicates that currently, while seamless integration is the eventual aim, they are unable to comply with many standard, routine ATM procedures. This has not prevented RPAS operations, but has limited their integration.

International regulations and standards require that any new system, procedure or operation that has an impact on the safety of ATM operations shall be subject to a risk assessment and mitigation process to support its safe introduction and operation. The goal of safe RPAS integration into the ATM system, with special attention to surface operations, is subject to standard Safety Management System (SMS) principles. RPAS are classified as 'aircraft' and ultimately should comply with all the rules established for flying, certifying, and equipping aircraft. A key factor in safe surface operations by RPAS is their ability to act and respond in an equivalent way to manned aircraft and there shall always be a pilot responsible for the RPAS operations. In addition the RPAS shall interface with Ground Based Airport systems.

SESAR Solution PJ03a-09 investigates ways in which RPAS may be able to use technical capability and procedural means to comply with ATC instructions in order to be integrated in surface operations with other manned traffic[1]. The scope of this work is to present the results collected during a dedicated validation exercise performed by ENAV and his Linked Third Parties (Techno Sky, NAIS, IDS) in Napoli Capodichino Airport Center with participation of Air Traffic Controllers, RPAS pilots, RPAS Safety and Human Factor experts. Specific use cases related to "taxi-in" and "taxi-out" operations in both nominal and contingency situations (loss of command and control, loss of communication) were assessed based on the Taranto Grottaglie Airport environment. Special attention was given to the use of a dedicated interactive Airport Moving Map for RPAS Ground Control Station (GCS) analyzing the impact of its usage on operations and actors involved in terms of Human Factor and Safety KPAs. This paper is outlined as follows: Sec.II provides a description of exercise, Sec.III describes the validation scenario, section IV provides a description of Airport Moving Map for GCS, sections V and VI contains the conclusions and recommendations.

II. Exercise Description and Scope

A. General Description

For this V1[1] validation exercise led by ENAV the main objective was the evaluation of the concept identified by Solution 03a-09 through the use of gaming simulation technique.

The scope was to assess the operational concept of introduction of RPAS traffic surface operations in current ATM environment.

The gaming simulation was executed through a dedicated workshop with participation of operative personnel (Air Traffic Controllers and RPAS Pilots), Key Performance Area (KPA) and RPAS experts. This validation represents the first example of validation exercise in SESAR program focused on RPAS surface operations in airport environment.

B. Validation exercise technique

Focus Group

The focus group technique is a qualitative research methodology used to explore the opinions, knowledge, perceptions, and concerns of individuals in regard to a particular topic. In the scope of this exercise, focus groups represented a reliable validation technique useful to stimulate a structured debate among multiple parties or roles. Discussions were led in an interactive group setting, where participants were free to talk with other group members about the issues presented by the validation expert.

Focus groups allowed obtaining a wide variety of views from a number of people who might have different but equally relevant perspectives about the use and the impact of the new operational concept.

During the focus group sessions, stakeholders were provided with different kinds of information and were asked to discuss about the different use cases proposed, highlighting the differences between the current surface scenario and the proposed new scenario with RPAS traffic in terms of working method and duties

This method used in combination with questionnaires ensured to the Human Factor (HF) and Safety (SAF) team to collect the feedback of ATCOs and RPAS Pilots involved. In designing and conducting the focus groups following guidelines were taken into account:

- Participants were carefully recruited for effective and authoritative responses;
- The environment were comfortable, with circle seating, tape recorded;
- The moderators were skillful in group discussions, introduced agenda and goals of the session, used pre-determined discussion agenda/questions, established permissive environment;
- Discussion topics were presented in a clear manner to encourage controllers and RPAS pilots to give sufficient thought;
- Analysis and reporting was based systematic analysis, verifiable procedures, appropriate reporting

[1] V1 Maturity Phase according to EUROCONTROL European Operational Concept Validation Methodology (E-OCVM)

The focus group session was useful to elicit global user perception feasibility and benefits of concept under assessment

Questionnaires

Questionnaires allowed obtaining a wide variety of views from a number of people who might have different but equally relevant perspectives about the use and the impact of the new operational concept. Used in combination with focus groups they ensured the HF and SAF team to collect the feedback of all stakeholders involved, thus avoiding producing final results biased. In designing and administrating the questionnaires the following guidelines were taken into account:

- they were shorted to encourage controllers and pilots to give sufficient thought to each question;
- the questions were precise to only permit one possible interpretation;
- the questions were short and written in simple English to facilitate understanding for non-native English speakers;
- questions avoided abstractions and concepts and focus on practical issues.

The questionnaires were submitted to the controllers and pilots after the completion of focus group session. The questionnaire elicited global user perception feasibility and benefits of concept under assessment.
It is important to notice that questionnaires and focus groups are deeply interconnected techniques. This means that on one hand, data collected though the focus-groups were then verified and discussed during the debriefings, and from the other hand insights emerged during the debriefings were used to guide the following sessions. This combination of techniques was proved to ensure the correctness and the reliability of the results obtained.

Ad hoc questionnaires were used to assess the impact on ATCOs and RPAS Pilots working method in terms of SAF and HF, related the integration of RPAS traffic in airport operations.

III. VALIDATION SCENARIO ASSUMPTIONS AND USE CASES

Scenario

The Airport selected for validation activities was Taranto Grottaglie (LIBG). Located in the south of Italy in Pulia Region. According to the airport Classification reported in the SESAR 2020 PJ19 Concept Of Operations**Errore. L'origine riferimento non è stata trovata.** Grottaglie has the following characteristics:

- Airport Simple Runway and Layout system
- Low Complexity
- Low Density

The airport layout is quite simple with a single runway, two aprons and three taxiways:

Figure 1: Grottaglie airport layout

Through a decision taken on July 14th, 2014, ENAC (Italian Civil Aviation Authority) devised a plan for the Taranto-Grottaglie airport (appointed as a National Interest airport on the Airports National Plan) in order to qualify it as an integrated logistic platform aimed at research, development and experimentation hub for aeronautics related products with particular attention to RPAS[3].

Assumptions

Integration of RPAS surface operations in airport environment is challenging due to the fact that RPAS will have to fit into the ATM environment and adapt accordingly. Many RPAS aspects such as latency and see and avoid functionality have never been addressed before within this environment for manned aviation, simply because of the fact that a pilot is on-board the aircraft, capable of handling these issues in a safe and timely manner. Also, these human capabilities have never been translated into system performance as they were placed under "good airmanship" for see and avoid, or simply not addressed at all. Manned aviation is considered as safe due to the contributions of many factors (such as the ATC system, safety nets, cockpit automation etc.). These factors are now challenged by the introduction of a new airspace user, with high number of flights, different sizes and types. This challenge relies on the quantification of these safety attributes, due to the introduction of new aspects such as latency of communications, and contingency. It also shows up potential areas where improvements are required in manned aviation (such as See and Avoid rule).

It is assumed that all RPAS operating on ground in airport environment shall comply with the relevant requirements in the same manner as manned aircraft. Surface operations where

Identify applicable sponsor/s here. *(sponsors)* transport aircraft normally operate could require additional performance requirements covering:

- Maneuverability
- Latency in voice or data link communication
- Interoperability with ground based airport systems
- Detect and Avoid

The overall approach towards RPAS integration is that RPAS have to fit into the ATM system and not that the ATM system needs to be adapted to RPAS, to enable safe integration. The vision behind this concept is that RPAS, when meeting all the technical and regulatory requirements, are to be treated like any other airspace user. RPAS operations will certainly also have to be as close as possible to manned aviation for ATC purposes as it will not be possible for controllers to effectively handle many different types of RPAS with different contingency procedures.

Considering the V1 maturity phase, assumptions adopted by this validation exercise, are summarized as following:

- RPAS HALE/MALE Aircraft with following capabilities**Errore. L'origine riferimento non è stata trovata.**:
    - o RPAS performances in compliance with air traffic rules and airport use;
    - o RPAS was able to meet Communication Navigation and surveillance (CNS) airspace requirements
    - o RPAS remained clear to other airspace users manned and unmanned
    - o RPAS Airport Moving Map (AMM) was interoperable with airport systems
    - o Information shown on AMM are coherent with ones received via data link

- It was assumed that data link was available to enable route and clearance exchange between ATC and the RPAS.
- It was assumed that traffic during the gaming was mixed: RPAS/Manned

Use Cases

Six different use cases (nominal / contingency) and related operational working method were addressed by this exercise. They are summarized in the following bullets:

- **UC_1 Taxi-in operation**: after landing, RPAS exits from runway using the taxiway and reaches the stand.
- **UC_2 Taxi-out operation:** from the stand, RPAS uses the taxiway and reaches the runway (line-up) for departure
- **UC_3 Taxi-in operation + non nominal situation (contingency):** after landing, RPAS exits from runway using the taxiway and reaches the stand. A contingency situation (loss of communication) is occurring.
- **UC_4 Taxi-out operation + non nominal situation (contingency):** from the stand, RPAS uses the taxiway and reaches the runway (line-up) for departure. A contingency situation (loss of communication) is occurring.
- **UC_5 Taxi-in operation + non nominal situation (contingency):** after landing, RPAS exits from runway using the taxiway and reaches the stand. A contingency situation (loss of C2 link) is occurring.
- **UC_6 Taxi-out operation + non nominal situation (contingency):** from the stand, RPAS uses the taxiway and reaches the runway (line-up) for departure. A contingency situation (loss of C2 link) is occurring.

IV. Airport Moving Map Description

During the “taxi-in” and “taxi-out” operations, the RPAS pilot was provided with an Airport Moving Map (AMM) to help him/her to orient the RPAS’ position on the ground in relation to runways, taxiways and airport structures, without reference to paper charts.

The AMM allows the RPAS pilot having two different display modes based on different orientation of airport map.

The **Track Up** (Fig.2) is the default display mode. In this mode, map orientation is bound to RPAS’ one, the map is rotated so that the RPAS' icon remains up and the ground trajectory is displayed vertically in the center of the display. This visualization mode simplifies flight control because all turns are simply left or right of the RPAS's current heading, represented by a compass in the middle of the display.

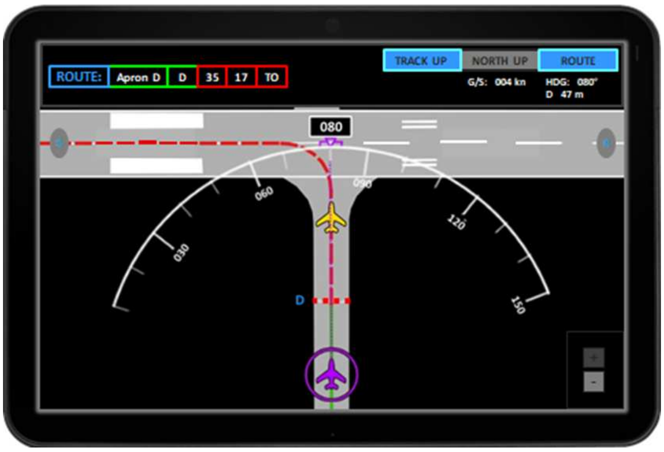

Figure 2: Track Up Mode

The **North up (**Fig.3), allows RPAS pilot to keep the orientation of the map stationary. In North-Up mode, the RPAS icon on the map will change direction to show how the RPAS is moving from the North on the map. In this mode, the RPAS Pilot can also use the pan function to navigate as desired on the map (e.g. to explore the airport area along the planned route).

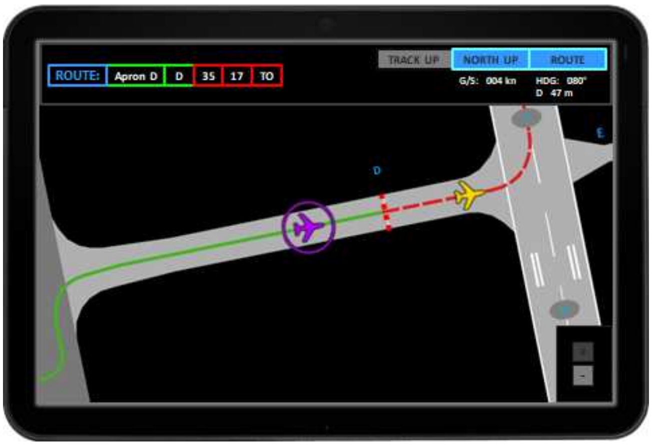

Figure 3: North Up Mode

In both visualization modes, it is possible to visualize or hide the ground trajectory by selecting/deselecting the command ROUTE and it is possible to zoom in and out to have a view of different areas in the airport and to adjust the amount of details shown on the display.

In the AMM the following graphic elements are used to represent all relevant information for surface movements during the "taxi-in" and "taxi-out" operations:

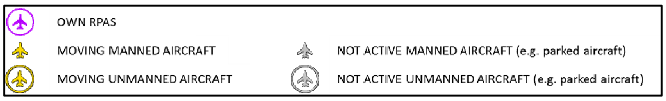

Figure 4:Manned/Unmanned Status

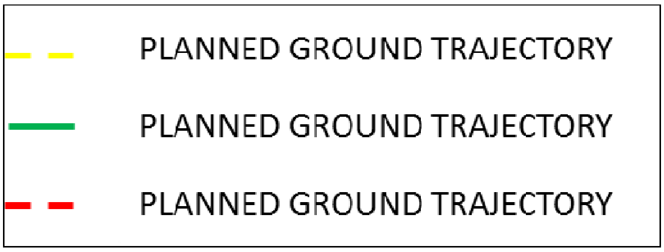

Figure 5: Ground Trajectory Status

The following label structure is used in the AMM to display all aircraft's information during surface operations. The RPAS are identified with a "U" at the end of aircraft type as show in the Fig.6

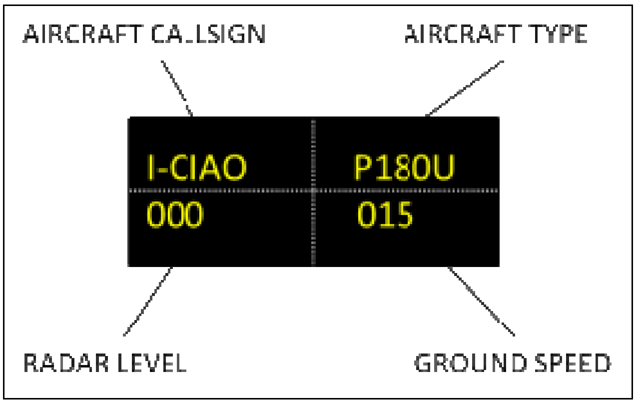

Figure 6: RPAS Label

The Airport Moving Map display is split in two main windows: the **Command/Information Window** at the top of display and the **Map Windows**

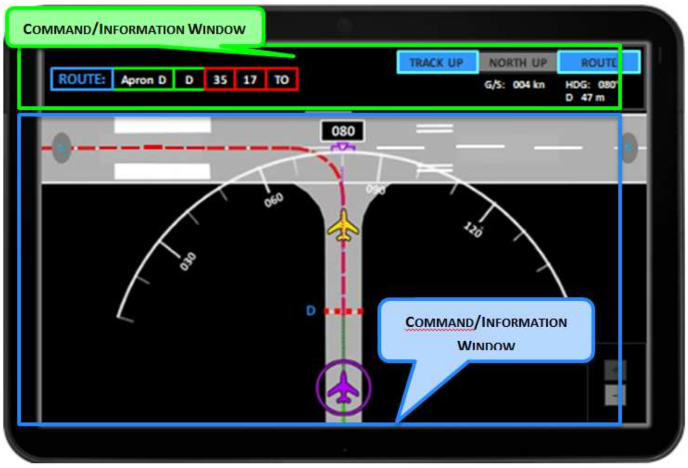

Figure 7: AMM Windows

V. Conclusions

The integration of RPAS in airport environment for surface operations represents a "must" for the future complete integration of RPAS into ATM. The main general requirements for a safe future integration can be reassumed with the following bullets:

- RPAS shall comply with existing and future regulations and procedures;
- The integration of RPAS shall not imply a significant impact on the current users of airport;
- RPAS integration shall not compromise existing aviation safety levels nor increase risk: the way RPAS operations are conducted shall be equivalent to that of manned aircraft, as much as possible;
- RPAS must be transparent and recognizable (alike) to ATC and other airspace users.

The discussion, questionnaire and focus group carried out during the gaming simulation, were oriented taking into consideration the above mentioned bullets as starting point and necessary conditions and the maturity of the solution.

Recommendations, operational working methods, Human Factor and Safety outputs were collected for the 6 different use cases analysed according to the scenario used (Grottaglie-Taranto Airport).

Looking at Use cases 1 (Taxi in) and 2 (Taxi out) in nominal conditions, from the outputs, ATCO and RPAS pilot working method is not different from manned aviation working method in terms of clearances.

Special recommendations, which will be converted in operational requirements, are related to RPAS identification during communication and also on Controller Working Position. In detail the "unmanned" nature of the RPAS shall be clearly communicated by RPAS pilot to ATCO via dedicated phraseology. The same "identification" concept is extended to the RPAS call sign and to a dedicated symbol on ATCO Human Machine Interface (HMI) useful to inform the controller that aircraft is an RPA.

The analysis of use cases 3-4-5-6 provides information about the impact on working method during the specific RPAS "contingency" situations like as loss of communication and loss of Command & Control link during taxi-in and taxi-out operations.

During loss of communication link, the main aspect is related to a need of an alternative G/G communication link (ground telecommunication system) between RPAS pilot and ATCO to be uses in case of other typical communication links are interrupt (voice communication channel, datalink, emergency frequency 21.5khz).

In case of loss of C2 link during taxi-in/taxi-out operations, was clear to the actors the need of stopping the RPAS through an auto breaking system and the capability to activate an engine off from ground control station. This system shall be independent from C2 link. This shall be considered as a technical/operational requirements to allow RPAS integration on airport operations. Could be even important to envisage an initial standardization of contingency procedures among same RPAS class/category.

The need to train (or brief) the ATCO on specific technical performances of any foreseen RPAS specific vehicle/model operating within his/her are of responsibility was also arised.

Additionally, the usage of Airport Moving Map can bring benefits in terms of Pilot situational awareness and workload during the ground operations (i.e. taxi-in and taxi-out), hence in term of safety. AMM allows the pilot to have graphically clear and immediate information regarding the ownership's position, the ground trajectory to follow during the taxi operations and all concerned ground traffic movements. In addition, it provides data in case of nominal and non-nominal situations (contingencies) useful to increase pilot's situational awareness.

To better manage all information, AMM should be integrated in the Pilot Ground Control Station and its HMI elements need to be as coherent as possible to those ones currently used.

VI. Recommendations And next steps

The following recommendations (Technical and operational) have been extracted from the focus groups held during the exercise:

- In case of loss of communication link between RPAS Pilot and ATCO an alternative communication mean shall be used (RADIO or Telephone G/G alternative mean identified in Flight Plan)
- During voice communication the "unmanned" nature of the RPAS shall be clearly communicated by RPAS Pilot to ATCO. Ad hoc phraseology shall be defined
- The ATCO shall be able to identify the RPA on their CWP through a dedicated symbology.
- Dedicated element into the RPAS's callsign shall be defined to clearly distinguish manned aircraft from unmanned aircraft in both AMM and ATCOs CWP (e.g. The last character of the RPAS' callsign shall be the letter "U" to indicate an unmanned aircraft[2]);
- In case of similar callsign, ATCO shall request the "extended" callsign
- In case of loss communication RPAS pilot can be treated as in Extended VLOS procedure (e.g. Marshaller supporting operations);
- The loss of video-signal is an extra non-nominal condition to be investigated;
- RPAS camera shall be able to identify and discriminate airport ground marks and signs and lights during surface operations. Technical performance of the camera shall allow the clear detection and understanding of all colour based information e.g. light, ground signal. Camera view angle shall reflect the human eyes view angle that is 165/170°.
- RPAS shall be equipped with an auto breaking system and the capability to activate an engine off from ground control station to be activated in case of loss of C2 link during surface operations. This system shall be independent from C2 link. This shall be considered as a technical/operational requirements to allow RPAS integration on airport operations
- ATCOs need to to be trained on specific technical performances of any foreseen RPA specific vehicles operating within his area of responsibility;
- Procedures to recover from contingencies depend on specific damages/behaviours that can be caused by any specific RPAS types;
- The Airport Moving Map should be, if possible, fully integrated into the RPAS Ground Control System display;
- HMI Elements in the Airport Moving Map shall be as coherent as possible with the HMI elements currently used in the RPAS Ground Control System. (e.g. ownership shall be displayed in green colour in the Airport Moving Map like RPAS Ground Control System HMI[3]);
- In case of temporary closure, Taxiway status shall be displayed in the Airport Moving Map through a dedicated symbology (e.g. using a red cross marker);
- A Custom Up visualization mode should be implemented in the Airport Moving Map to make it user friendly from Pilot perspective (e.g. typing on the keyboard the desired map's orientation)
- Dedicated PAN Buttons in all Airport Moving Map visualization mode shall be added to make easier the map navigation;
- An ad hoc Airport Moving Map button shall be added to allow the pilot to centre the map on ownership;
- Specific operations like backtrack and line-up shall be clearly displayed in the Airport Moving Map Route Strip (e.g. back track operation should be indicated with the prefix B before the runway number and line up operation with the prefix L before the runway number);
- Only the relevant taxi-in information shall be displayed on the Airport Moving Map (e.g. indications about landing phase and assigned runway are considered not necessary from the pilot perspective)

[2] This shall be coordinated with the Regulatory Authority

[3] In line with Ingegneria dei Sitemi IDS Ground Control Station

- During the taxi-in operations, planned ground trajectory shall be displayed to the Airport Moving Map just after the touchdown;
- RPAS Pilot shall receive on the Airport Moving Map information about a loss of datalink when it occurs (e.g. the message "LOSS OF DATALINK" shall appear in the Airport Moving Map Route Strip);
- When loss of datalink occurs, the track shall be hidden providing to the RPAS Pilot only the ownership's position on the Airport Moving Map;
- In order to improve the Pilot situational awareness during the taxi-out operations, on the Airport Moving Map the arriving aircraft above 1000 ft shall be filtered.

The outputs related to concept under investigation represent a good starting point for the next V2 Real Time Simulations activities scheduled during next year. This exercise planned in 2019, will be carried out with use of an airport simulation platform and a RPAS cockpit simulator with participation of ATCOs and RPAS pilots in a real time environment.

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