Honeywell

STATEMENT OF WORK FOR BRNO UNIVERSITY OF TECHNOLOGY

TESTBED DESIGN AND REALISATION IN "L-BAND UNMANNED AERIAL VEHICLE TRANSCEIVER FOR CONNECTIVITY IN ALL FLIGHT PHASES" (ARTES 4.0 4S SPL 7C.069 /4S.022)

September 2023

L-BAND UNMANNED AERIAL VEHICLE TRANSCEIVER FOR CONNECTIVITY IN ALL FLIGHT PHASES (ARTES 4.0 4S SPL 7C.069 /4S.022)– DESCRIPTION OF WORK FOR TESTBED DESIGN

1. Context

This document provides a description of work for a testbed design for testing a L-Band LEO & GEO compatible UAV SATCOM transceiver that can provide connectivity in all flight phases. The testbed is expected to be used to test and verify the performance of the transceiver(s) in the laboratory in terms of throughput, availability, latency and reliability while considering different roll, pitch, yaw angles and direction of arrival from different orbits, as required from all the UAV flight phases and in the presence of different emulated ground morphology. A work breakdown structure and flow of work can be seen in Figure 1-1 **Error! Reference source not found.** below.

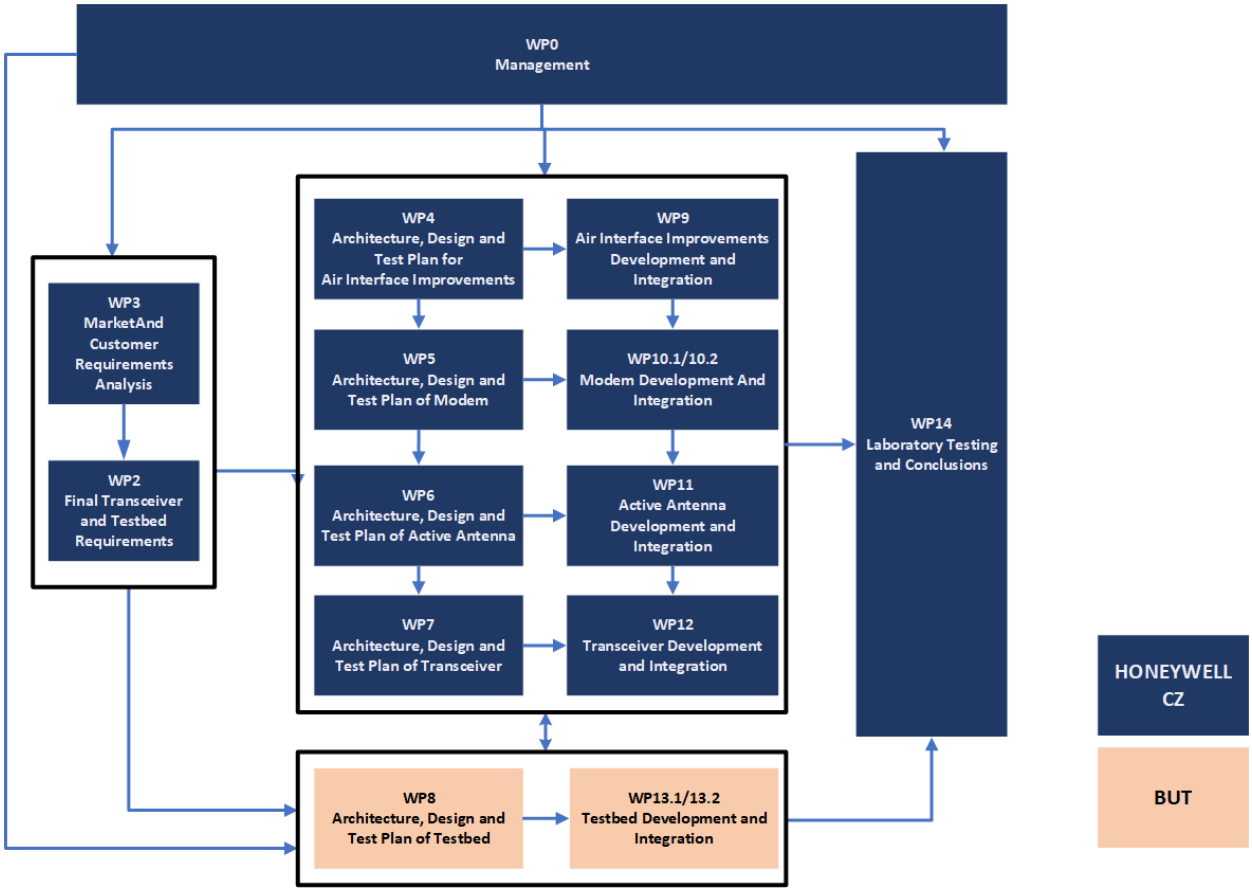

Figure 1-1 LEO / GEO Terminal and Testbed Development work breakdown structure and workflow

2. Reference Documents

[1] "L BAND UNMANNED AERIAL VEHICLE TRANSCEIVER FOR CONNECTIVITY IN ALL FLIGHT PHASES (ARTES 4.0 4S SPL 7C.069 /4S.022)" – ESA Statement of Work

[2] Appendix 3 to ESA AO/1-11196/22/UK/ND – "SPECIAL CONDITIONS OF TENDER"

[3] "L BAND UNMANNED AERIAL VEHICLE TRANSCEIVER FOR CONNECTIVITY IN ALL FLIGHT PHASES (ARTES 4.0 4S SPL 7C.069 /4S.022)" – Honeywell IMPLEMENTATION PROPOSAL

[4] "L BAND UNMANNED AERIAL VEHICLE TRANSCEIVER FOR CONNECTIVITY IN ALL FLIGHT PHASES (ARTES 4.0 4S SPL 7C.069 /4S.022)" – Honeywell TECHNICAL PROPOSAL

[5] L-band UAV Terminal for connectivity in all flight phases AO 11196 Negotiation meeting – Minutes of Meeting, June 21st 2023

3. Work description

Architecture, Design and Test Plan of Testbed

The objective is to establish the architecture, the detailed design and the test plan of a testbed that is to verify the performance of the SUAV (Satellite-Capable UAV) for the selected satellite scenarios of Output 1.3 in [1]. BUT's work plan shall lead to the timely delivery of the following outputs:

- Documented definition of quantified, complete, traceable and verifiable requirements, with due justification, for a SUAV performance verification testbed that is to evaluate the end-to end performance of the SUAV for the selected satellite scenarios of Output 1.3 of [1].
- In his definition of the testbed requirements, the Contractor shall follow the requirements of Appendix 1.2 of [1] replicated here in Section 4. Whenever needed, the BUT shall adjust these requirements, with due justification.
- Documented definition of the architecture and of the detailed design of the SUAV performance verification testbed.
- Documented definition of a test plan for the performance verification of the SUAV for the selected satellite scenarios in Output 1.3 (of Ref. [1]) via the testbed.

Expected Deliverable: TN4.1: Testbed Architecture, Design and Test Plan

UAV Performance Verification Testbed

The objective is to develop and/or procure the necessary testbed elements and integrate them to form the testbed.

BUT's work plan shall lead to the timely delivery of the following outputs:

- Complete and integrated HW, FW and SW parts of the SUAV performance verification testbed that is to verify the performance of the SUAV for the selected system architecture scenarios of Output 1.3 {Ref. [1]) and in accordance with the agreed architecture and design of Testbed as described in Architecture, Design and Test Plan of Testbed section above.

- BUT is advised to use COTS units for the emulation of the satellite link and the SUAV controller, as far as practically possible.
- Documented functional verification of the SUAV performance verification testbed in the laboratory, in accordance with the test plan of Architecture, Design and Test Plan of Testbed section above.
- A user manual clearly describing the use of the HW and SW parts of the testbed as would be needed in verification tests.
- Participation in WP14 test activities. Please note that final verification tests will be performed in a large anechoic chamber at a European test site. Travel to the premises and presence and participation in the execution of tests will be required.

Expected Deliverables:

- Contribution to TN5.1: Testbed Verification Report
- UAV Performance Verification Testbed, SW, FW and HW parts

4. Requirements

Requirement ID (ESA SoW)	Requirement
REQ-OUT4.1-010	The testbed shall be able to emulate in the laboratory the end-to-end satellite communication links between the SUAV and an UAV controller
REQ-OUT4.1-020	The testbed shall be able to support the testing of any satellite capable UAV platform, in a plug and play fashion provided that RF signal connectors to the transceiver and appropriate control interface (physical interface and the control software) are available. The maximal number of transmit/receive antennas is expected to be limited to 1 / 2, respectively for F/L and R/L link, unless further study during the course of the project requires differently.
REQ-OUT4.1-030	A COTS satellite link emulator can be an element of the testbed to emulate the satellite link and the satellite impairments.
REQ-OUT4.1-040	Real or emulated, HW or SW, COTS units can be used for the UAV controller side.
REQ-OUT4.1-050	The testbed shall be able to emulate the selected satellite system architecture scenarios of Output 1.3.
REQ-OUT4.1-060	The testbed shall be able to emulate ground morphology and blocking conditions.
REQ-OUT4.1-070	The testbed shall be able to emulate all possible operational roll/pitch angles for all yaw angles.
REQ-OUT4.1-080	The testbed shall be able to emulate the elevation and azimuth angles to the satellites

REQ-OUT4.1-090	The testbed shall offer both F/L and R/L functionality as necessary.
REQ-OUT4.1-100	The testbed shall be able to emulate link handover between different on-board transceivers in case such installation has been selected.
REQ-OUT4.1-110	The testbed shall be able to emulate link handover between different satellites in case such satellite system architecture has been selected.
REQ-OUT4.1-130	The testbed shall be able to access as a minimum the following performance figures of merit (see Appendix 1.3 in Ref [1] for the definitions): • SNR • Throughput at PER 10^{-3} • Latency • Availability • Transaction time • Continuity • Integrity in all possible operational DoA from different orbits, as required from all the UAV flight phases and in the presence of different emulated ground morphology.
REQ-OUT4.1-140	Regarding availability, integrity and continuity, which are figures of merit related with a full flight duration, the testbed shall have the capability to be loaded by real or realistic roll/pitch/yaw and elevation/azimuth statistics, at least on a successive frame by frame manner, with the frame duration specified based on the preliminary study, and perform their evaluation for the full flight.

5. Reporting and delivery

Deliverables

The activity will be run in accordance with the workflow described in Figure 1-1. BUT will interact with other work packages (collecting inputs from WPs 2 and 3, providing updates during the execution of WPs 4-12 and providing input to WP14) for the smooth execution of the project. In addition, BUT will be the prime responsible for:

- "TN4.1 – Testbed Architecture, Design and Test Plan" document
- "Verification Testbed Design Review (VTDR)" to be hosted at BUT's premises unless combined with another review within Honeywell's responsibility conducted at the same time
- "HW2 – UAV Performance Verification Testbed, HW parts (minimum two sets)" deliverable

- "SW2 – UAV Performance Verification Testbed, SW and FW parts" deliverable

BUT will also contribute to:

- "TN5.1 – Testbed Verification Report" deliverable to be delivered at Test Readiness Review and updated for the Final Review.

Delivery dates

The activity will start on October 9, 2023 (shown as T0 in the table below) and run for 24 months, with the last 6 months strictly reserved for WP14 and project closure activities. A detailed project plan of BUT related activities will be shared once available, and the dates below are subject to change. Current estimates for BUT related deliveries are:

Deliverable	**Required Date for Delivery to Honeywell**	**Required date for submission to ESA**
Preliminary Design Review with Honeywell	T0 + 6 months	
TN4.1 – Testbed Architecture, Design and Test Plan	T0 + 8 months	T0 + 8.5 months
Verification Testbed Design Review (VTDR)		T0 + 9 months
Contribution to draft TN5.1 – Testbed Verification Report	T0 + 14 months	T0 + 14.5 months
HW2[1] (minimum two sets)	T0 + 14 months	T0 + 24 months
SW2	T0 + 14 months	T0 + 24 months
Contribution to final version of TN5.1 – Testbed Verification Report	T0 + 23 months	T0 + 24 months

Document priority order

In case of any discrepancy or disagreement between documents, the following order of priority

- Minutes of Meeting for the Project Negotiation Meeting held with ESA on June 21st, 2023 [5]
- ESA Statement of Work [1]
- Honeywell Proposal [3, 4]

End of the document

[1] Hardware will be submitted to ESA and become ESA property. This should be taken into account in project costing.