**1.0 INTRODUCTION**

**1.1 PURPOSE**

The purpose of this document is to describe the verification of various operational scenarios for voice and audio communications (VAC) described in CCSDS 766.2-R-0, Proposed Draft Recommended Standard for voice and audio communications. All of the use cases stated in this book are currently in use on the International Space Station (ISS) and the extended ground segment including television and radio stations. Therefore, discreet testing or prototyping of use case scenarios from the voice book are not required.

**1.2 SCOPE**

The scope of this document is validation of both digital voice using the established communication networks (T1/E1) and VoIP over the same networks or public internet. Audio file transmission is considered standard file exchange using the AAC and Mpeg3 audio file formats. Voice communication systems for spacecraft applications and space to ground transmission are used in an everyday basis on the ISS.

Spacecraft-to-spacecraft are used between the Soyus capsule and the ISS since several years, the same system was used between the ISS and the Space Shuttle, for these reasons prototyping and validation are also not part of this yellow book. This book does not call Astronaut to Spacecraft as a separate operational scenario. It is used in every EVA with Russians or American space suits with the ISS and the MCCs. Rather, the operational scenarios in the voice and audio communications book can be applied to spacecraft-to-spacecraft as well as spacecraft-to-ground (4.1 and 6.1). The systems needed for transmission and reception of voice signals in these two cases falls beyond the scope of the book and are covered under other CCSDS protocols.

Validation of specific applications/use-cases listed in the voice and audio communications book in Section 3, 4 and 6 has been done. The sections 5 and 7 are also used by the American, Chinese and Russian Space Agencies.

**1.3 APPLICIBILITY**

The voice and audio communications book is applicable to voice applications in spaceflight as listed in 5 cases of the book. This includes all use cases and technical specifications as listed in Section 2 of the voice and audio communications book.

**1.4 RATIONALE**

The CCSDS Procedures Manual states that for a Recommendation to become a Blue Book, the standard must be tested in an operational manner. The following requirements for an implementation exercise were excerpted from reference [1]:

“At least two independent and interoperable prototypes or implementations

must have been developed and demonstrated in an operationally relevant

environment, either real or simulated.”

This document outlines the voice and audio communications Working Group’s approach to meeting this requirement for the voice and audio communications book.

**1.5 DOCUMENT STRUCTURE**

Section 2 of this document provides a summary and conclusions from validation and testing to date.

Section 3 outlines validation and test goals.

Section 4 provides an overview of what was validated and tested.

Section 5 provides greater detail for each of the scenarios.

Section 6 documents the results.

**2.0 SUMMARY CONCLUSIONS/RECOMMENDATION**

Current systems onboard the ISS have implemented the protocols listed in the voice and audio communications book for voice communications. Voice or voice embedded in the Video being acquired and transmitted from the ISS, regardless of which agency’s cameras, microphones or headsets are acquiring it, is being distributed as required to every space agency participating in ISS activities and to the public through the media using G.728, G.711voice compression or ACC for internet applications like YouTube or others. Also telephones or microphones connected via telephone lines to a MCC are used for audio communications between the crew of the ISS and the general public.

Based on the current systems being complaint with the voice and audio communications book the voice and audio communications Working Group recommends this book be promoted to a Blue Book CCSDS Recommended Standard.

**3.0 VAC VALIDATION AND TEST GOALS**

The goal of the validation is twofold:

1. Demonstrate that current International Space Station (ISS), spacecrafts like Soyuz capsules or Dragon voice systems are in compliance with the voice and audio communications book for several of the applications/use-cases.
2. Prototype applications/use-cases that are not currently being used in operations from/to the ISS or any other spacecraft. The prototype is to use simulation systems available for testing ISS components on the ground. This will provide an adequate simulation of an existing spacecraft system so as to understand the characteristics of the non-flown applications and use-cases.

**4.0 VALIDATION AND TEST OVERVIEW**

Most of the standards in this book have been adopted for the voice systems onboard the ISS and most of the MCC over USA, Russia, Japan, China? and Europe, providing a daily proof of concept and operation using the standards listed. This is not coincidental as members of the voice and audio communications working group have been involved in the development of these systems. These systems are considered to be a successful implementation of this book as they are considered acceptable for their respective application by the end users. The voice and audio communications book Section 2 states the voice quality of a system is not measured by application of the book, but rather by users of the system. That is, it is considered a success if the end user finds the quality to be acceptable for their purpose (QoE or QX). Based on that measure of success, each of the applications listed in Sections 3 to7 are successful.

**4.1 Summary of Tests**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Test | Application | Encoding | Spacecraft | Destination |
| 1 | Voice communications  inside of a MCC | G.711, VOIP | N/A | Various, depending how many buildings are the MCC |
| 2 | Voice communications  between MCCs | G.711, VoIP | N/A | NASA, ESA, RSA, JAXA, DLR, CNES |
| 3 | Voice communications  between a MCCs and external facilities | G.711, VoIP, telephone lines | ISS | NASA, ESA, RSA, DLR, CNES, ASI, JAXA, external |
| 4 | Public Affairs | G.711, VoIP, telephone lines | ISS / Soyuz | NASA, ESA, RSA, DLR, ASI, CNES, JAXA / external |
| 5 | Space to ground voice systems | G.711 / G.728 | ISS / Soyuz | NASA, JAXA, RSA, CNES, DLR |
| 6 | Emergency voice communications | G.728 / UHF | ISS / Soyuz | NASA, RSA, JAXA, China?? |
| 7 | Rendezvous, proximity and docking communications | G.728 / UHF / VHF | ISS / Soyuz | NASA, ESA, RSA, JAXA? China? |
| 8 | Search and rescue voice communications | UHF / VHF | Soyuz | RSA, other entities |

**5.0 VALIDATION PLAN DETAILS**

Note: the voice and audio communications book is clear that this is not a quality standard. In Section 2, Overview, of the book states quality is based on the requirements of the end-user and they will have to work in conjunction with system engineers to ensure adequate audio and voice quality for their application (QoE or QX).

**5.1 Test #1 –VOICE COMMUNICATIONS INSIDE OF A MCC**

**5.1.1 SCENARIO**

Perform R/T Voice communications and audio files playback using the local voice system, including all kind of keyset types, voice loops, voice formats and recording devices (Voice and Audio communications book 2.2, 2.1.2, 2.1.3, 2.1.4, 2.2, 2.3, 2.3.1, 2.3.2, 2.3.2.1, 2.3.2.2, 2.5, 3.2, 3.2.2, 3.4).

The connectivity for the keysets (VoIP or T1) runs through the MCC LAN to the voice matrix or voice switch, then through internal network back/from inside of one control room or to others control rooms inside of the same Building or distributed to / from different buildings.

The playback of the voice loops can be done from the keyset itself or from the central voice recorder.

The Voice format change is coordinated with the planning and operations team. Different voice formats are applied for mission or operations mode, testing and simulations mode.

Different voice loops are selected inside of the different voice format according to the current operations mode.

**5.1.2 RESULTS**

Keysets, voice loops, voice playbacks and voice formats are used on a regular basis for voice communications. They use established network protocols for communication. The voice is being encoded as G.711. Variable voice formats and voice loops are employed, depending upon the current activity of the MCC. It is common to have more activities simultaneously in different control and support rooms inside of a MCC. Ground controllers routinely communicate with each other’s in different control rooms or buildings inside a MCC.

**5.2 TEST #2 VOICE COMMUNICATIONS BETWEEN MCCs**

**5.2.1 SCENARIO**

The voice communications between MCCs is done normally using T1/E1 interfaces or VOIP, the most common technology to connect the centers is using MPLS networks or others dedicated lines (Voice and Audio communications book 3.2.1, 3.2.2, 3.2.3, 3.3.1, 3.4, 3.5).

Participating space agencies are NASA, RSA, ESA, DLR, CNES and JAXA.

**5.2.2 RESULTS**

The ISS ground segment has a distributed network based on MPLS networks connecting all the User Space Operations centers across Europe, USA, Japan and Russia as well.

The common interface for the voice system are T1 (USA) and E1 (Europe and Russia). The codec used is G.711. Signaling is mandatory for the S/G loops used by NASA.

Channelization and voice formats definitions are an extremely important part of the design of the design of the voice communications.

All the voice loops and voice formats are quite well defined, but are also dynamic and always a coordination effort is needed to change voice loops inside a format.

Examples of common voice formats in Europe are the Columbus Operations (With JSC and Marshall), the ATV Operations (including CNES as well), the JMST Format (Joint Multi-Segment Training. Including the European Astronaut Center), the BCC format with Marshall, LSOS format and the European Simulation format among others.

Different kind of keysets is used in different continents, but all of them have a PTT function, off course.

Recording and playback functionalities are implemented at NASA, DLR, CNES and RSA.

Voice systems are used with the different voice format mentioned above for the corresponding operational scenarios in an everyday basis for the ISS project.

**5.3 TEST #3 VOICE COMMUNICATIONS BETWEEN MCCs AND EXTERNAL FACILITIES**

**5.3.1 SCENARIO**

MCC and research institutions or TV stations (Voice and Audio communications book 3.3.1, 3.4.1, 3.5).

Participating space agencies are NASA, RSA, ESA, DLR, CNES and JAXA.

**5.3.2 RESULTS**

TBW

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**5.4 TEST #4 PUBLIC AFFAIRS**

**5.4.1 SCENARIO**

Use of voice Public Affairs commonly combined with video (Voice and Audio communications book 3.3.1, 3.4.1, 3.5).

Participating space agencies are NASA, RSA, ESA, and JAXA.

**5.4.2 RESULTS**

TBW

**5.5 TEST #5 SPACE TO GROUND VOICE SYSTEMS**

**5.5.1 SCENARIO**

Space to ground communications using NASA or Russian channels (Voice and Audio communications book 4.2.1, 4.2.2, 4.2.3, 4.4, 4.5).

Participating space agencies are NASA, DLR, ESA, CNES, RSA and JAXA (china?)

**5.5.2 RESULTS**

TBW

**5.6 TEST #6 EMERGENCY VOICE COMMUNICATIONS**

**5.6.1 SCENARIO**

Emergency communications with ISS and Soyuz capsule (Voice and Audio communications book 5.2).

Participating space agencies are NASA and RSA

**5.6.2 RESULTS**

TBW

**5.7 TEST #7 RENDEZVOUS; PROXIMITY AND DOCKING COMMUNICATIONS**

**5.7.1 SCENARIO**

Rendezvous of Soyuz, ATC, HTVC, Space X and other vehicles (Voice and Audio communications book 6.2).

Participating space agencies are NASA, RSA, CNES and JAXA.

**5.7.2 RESULTS**

TBW

**5.8 TEST #8 SEARCH AND RESCUE VOICE COMMUNICATIONS**

**5.8.1 SCENARIO**

Acquire High Resolution Digital Imaging and transfer files to end-users (Voice and Audio communications book 7.1, 7.2).

Participating space agencies are NASA and RSA. China?

**5.8.2 RESULTS**

TBW

**6.0 SCENARIO RESULT DETAILS**

**6.1 SCENARIO #1 –**

**Summary**

|  |  |  |
| --- | --- | --- |
| 1 | Report Date |  |
| 2 | Program Under Test |  |
| 3 | Test Case Number |  |
| 4 | Agencies Participating | NASA, RSA, ESA, JAXA, DLR |
| 5 | Agency Responsible for Generating Audio | NASA, RSA, ESA, JAXA |
| 6 | Producing Test Engineer |  |
| 7 | Agency Responsible for Receiving Audio | NASA, RSA, ESA, JAXA |
| 8 | Receiving Test Engineer |  |
| 9 | Spacecraft | ISS |
| 10 | Results (Pass, Partial Pass, Fail) | Pass |
| 11 | Variances from Expected Result: | None |
| 12 | Comments | Currently being done between ISS crewmembers and ground participants |

**Details**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1 | Agency |  |  |  | Applicable Pics |
| 3 |  |  |  |  |  |
| 4 |  |  |  |  |  |
| 5 |  |  |  |  |  |

**6.2 SCENARIO #2**

**Summary**

|  |  |  |
| --- | --- | --- |
| 1 | Report Date |  |
| 2 | Program Under Test | Voice |
| 3 | Test Case Number |  |
| 4 | Agencies Participating | NASA, RSA, ESA, JAXA |
| 5 | Agency Responsible for Generating Audio | NASA, RSA, ESA, JAXA |
| 6 | Producing Test Engineer |  |
| 7 | Agency Responsible for Receiving Audio | NASA, RSA, ESA, JAXA |
| 8 | Receiving Test Engineer |  |
| 9 | Spacecraft | ISS |
| 10 | Results (Pass, Partial Pass, Fail) | Pass |
| 11 | Variances from Expected Result: | None |
| 12 | Comments | Currently being done between ISS crewmembers and ground participants |

**Details**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1 | Agency |  |  |  | Applicable Pics |
| 2 |  |  |  |  |  |
| 3 |  |  |  |  |  |
| 4 |  |  |  |  |  |
| 5 |  |  |  |  |  |

**6.3 SCENARIO #3**

**Summary**

|  |  |  |
| --- | --- | --- |
| 1 | Report Date |  |
| 2 | Program Under Test | Voice and Audio |
| 3 | Test Case Number | 3 – Situational Awareness |
| 4 | Agencies Participating | NASA, RSA, ESA, JAXA |
| 5 | Agency Responsible for Generating Audio | NASA, RSA, ESA,DLR |
| 6 | Producing Test Engineer |  |
| 7 | Agency Responsible for Receiving Audio | NASA, RSA, DLR |
| 8 | Receiving Test Engineer |  |
| 9 | Spacecraft | ISS |
| 10 | Results (Pass, Partial Pass, Fail) | Pass |
| 11 | Variances from Expected Result: | None |
| 12 | Comments | Routine daily ISS Operations |

**Details**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1 | Agency |  |  |  | Applicable Pics |
| 2 |  |  |  |  |  |
| 3 |  |  |  |  |  |
| 4 |  |  |  |  |  |
| 5 |  |  |  |  |  |

**6.4 SCENARIO #4 PUBLIC AFFAIRS**

**Summary**

|  |  |  |
| --- | --- | --- |
| 1 | Report Date |  |
| 2 | Program Under Test | Voice and Audio |
| 3 | Test Case Number | 4 – Public Affairs |
| 4 | Agencies Participating | NASA, RSA, ESA, DLR |
| 5 | Agency Responsible for Generating Audio | NASA, RSA, DLR |
| 6 | Producing Test Engineer |  |
| 7 | Agency Responsible for Receiving Audio | NASA, RSA, DLR |
| 8 | Receiving Test Engineer |  |
| 9 | Spacecraft | ISS |
| 10 | Results (Pass, Partial Pass, Fail) | Pass |
| 11 | Variances from Expected Result: | None |
| 12 | Comments | Routine daily ISS Operations |

**Details**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1 | Agency |  |  |  | Applicable Pics |
| 2 |  |  |  |  |  |
| 3 |  |  |  |  |  |
| 4 |  |  |  |  |  |
| 5 |  |  |  |  |  |

**6.5 SCENARIO #5**

**Summary**

|  |  |  |
| --- | --- | --- |
| 1 | Report Date |  |
| 2 | Program Under Test | Voice and Audio |
| 3 | Test Case Number |  |
| 4 | Agencies Participating | NASA, DLR |
| 5 | Agency Responsible for Generating Audio | NASA, DLR |
| 6 | Producing Test Engineer |  |
| 7 | Agency Responsible for Receiving Audio | NASA, DLR |
| 8 | Receiving Test Engineer |  |
| 9 | Spacecraft | ISS |
| 10 | Results (Pass, Partial Pass, Fail) | Pass |
| 11 | Variances from Expected Result: | None |
| 12 | Comments |  |

**Details**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1 | Agency |  |  |  | Applicable Pics |
| 4 |  |  |  |  |  |
| 5 |  |  |  |  |  |