Communications and Tracking of Visiting Vehicles near ISS: The design of the Reusable Launch Vehicle communications

Frederic H. Stillwagen

NASA Langley Research Center
Aerospace Systems Concepts and Analysis Competency Group
Hampton, VA 23681-0001
f.h.stillwagen@larc.nasa.gov

Abstract

The International Space Station (ISS) will provide for the visitation of various vehicles such as the Shuttle, Automated Transfer Vehicle (ATV), H-II Transfer Vehicle (HTV), Crew Return Vehicle (CRV), Reusable Launch Vehicle (RLV) and Soyuz. These vehicles will provide for crew replacement, consumables resupply, and equipment delivery. In order for these vehicles to approach and eventually dock with the ISS, there must be near continuous communications coverage between the visiting vehicle and the ISS, as well as communications between the vehicle and a Mission Control Center (MCC). Since the ISS communications systems are already designed and scheduled for ISS activation, the vehicles must either utilize these communications systems or provide their own. There are two means of two-way communications with the ISS. These are (1) S-Band communications using TDRSS, and (2) UHF communications using some form of the Space to Space Station Radio (SSSR) link. The RLV utilizes ISS compatible communications systems to communicate with both the ISS and a Mission Control Center. Since all vehicles must adhere to the Visiting Vehicle Interface requirements given in reference 1, the RLV communications system design must meet these requirements during entry into the ISS Approach Ellipsoid (AE) and during Proximity Operations. Included in this paper are descriptions of these communications approaches as well as their potential utilization in the ISS communications system.

Introduction

The Reusable Launch Vehicle (RLV) is one of many space vehicle concepts that may provide transfer capability to the International Space Station (ISS). The RLV concept provides for a vertical takeoff and horizontal landing, which is in direct correlation to Shuttle operations, with the exception that the RLV design has fixed propulsion and fuel storage tanks, which eliminates the need for jettisoning the fuel tanks. The RLV will communicate with the International Space Station (ISS) the same way as the Shuttle or a Visiting Vehicle (VV). The RLV provides a Shuttle comparable cargo bay that holds either an attached Crew Transportation Module (CTM) system or a Cargo Module (CM).

Communications between the RLV and the ISS adheres to the requirements set forth in the Visiting Vehicle Interface Definition Document (Ref 1). The RLV utilizes current communications systems available for the ISS (ref 2) to provide continuous communications with the ISS, Mission Control Center (MCC) and a Reusable Launch Vehicle Control Center (RLVCC). The approach utilizes communications system designs currently used on board the Space Shuttle Orbiter (SSO), as well as the communications systems on the ISS when docked to a NODE.

Communications systems within the RLV are made up of three basic capabilities:

1. RLV communications necessary to communicate with ISS, Mission Control Center Houston (MCC) and an RLVCC.
2. Crew Transportation Module communications with the same locations designated in (1) above during free flight and during ISS attached operations.
3. Crew Transportation module communications to MCC/ RLVCC during emergency abort sequences.

Capability 1 – RLV communications to ISS, MCC and RLVCC

The RLV is designed to provide both S-Band communications and UHF communications for operation during launch, orbit maneuvers, ISS Approach Ellipsoid entry, ISS Approach Initiation (Proximity Operations) and re-entry. The overall architecture for the RLV communications system is shown in Figure 1.

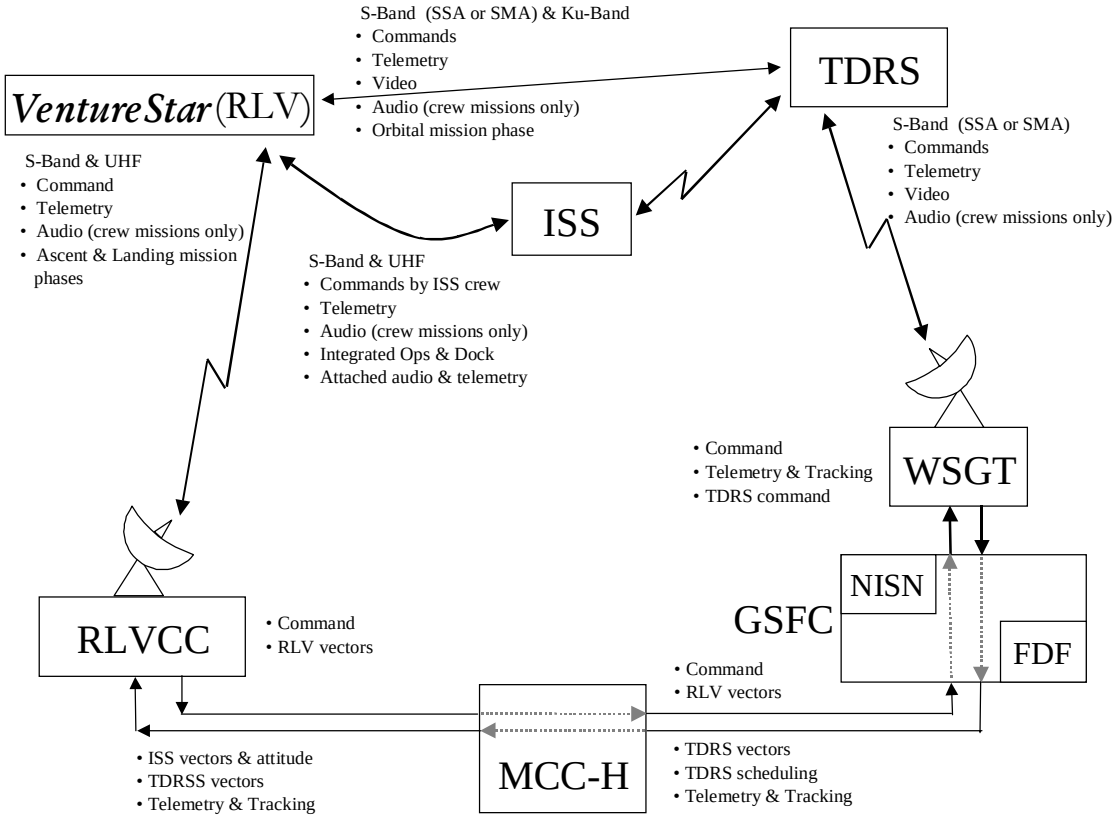

Figure 1. RLV Communications Architecture

Orbit, Approach and Rendezvous (AE, AI & Proximity Operations) with ISS. The RLV and the Crew Transportation module will provide continuous two-way communications (audio & data) to ISS, the MCC and to the RLVCC. Both S-Band and UHF communications will be utilized for crew interaction during these phases of the RLV mission to the ISS.

S-Band Communications

The RLV will be equipped with a redundant string of S-Band transponders (Generation IV) capable of communicating with the Tracking & Data Relay Satellite System (TDRSS) network in either S-Band Single Access (SSA) or S-Band Multiple Access (SMA) modes. These communications modes will be both forward and return links consisting of commands, telemetry and audio (Crew missions only). RLV S-Band TDRSS transponder characteristics are listed in Table 1. This transponder can also communicate with appropriately designated Ground Spaceflight Tracking and Data Network (GSTDN) ground sites, as well as a possible direct S-Band connection to the RLVCC. Upon launch and orbit insertion, the RLV will utilize the S-Band link through TDRSS for all data and audio communications with the MCC, RLVCC and the ISS. It is envisioned that this link will stay active throughout the mission until navigation into the ISS Approach Ellipsoid (designed as 4Km x 2 Km x 2 Km centered on the ISS Center of Gravity). Once the transition of the approach to ISS is made into the Approach Initiation (AI) zone, then a switchover to UHF communications with ISS will be made. Prior to continuing towards a docking maneuver with the ISS, continuous communications between the RLV and the ISS must be verified.

The RLV will be able to operate in both SSA and SMA modes to TDRSS in order to cover operational ranges and meet data transfer requirements. Return link data communications (voice & data) from the Crew to MCC or RLV-CC (via S-Band TDRSS) is expected to range between 50 – 300 kbps, depending which TDRSS mode (SMA or SSA) is utilized. Forward link rates from the MCC or RLV-CC to the Crew are expected to range between 10 – 100 kbps.

Table 1. RLV TDRSS characteristics

RLV S-Band link to MCC/RLVCC	Multiple Access	Single Access
Tx Frequency	2287.5 MHz	2265 MHz
Tx data rate	< 100 kbps	< 300 kbps
Rx Frequency	2106.4 MHz	2085.7 MHz
Rx data rate	<= 10 kbps	< 100 kbps

The RLV will utilize multiple external/internal (cargo bay) antennas to provide hemispherical coverage patterns. The RLV S-Band design will be similar to S-Band communications system approach of the Space Shuttle. The antennas are situated to provide maximum coverage to the TDRS network.

Ku-Band Communications

The RLV may utilize the Ku-Band Single Access (KSA) communications link to TDRSS for the purposes of transferring video to the ground. Though not a necessary Visiting Vehicle requirement for communications when on a mission to ISS, the Ku-Band link may have usefulness as an aide for deployment of commercial payloads. If appropriately mounted cameras are located within the RLV cargo bay, this system could also function as a tool to relay video to the MCC/ RLVCC when approaching the ISS.

UHF Communications

The RLV will be equipped with a redundant string of UHF radios capable of communicating with the ISS Space to Space Communications System (SSCS). The RLV UHF communications system design will be like the Space to Space Orbiter Radio (SSOR) capability (Ref 3), and will be able to communicate when the SSCS is in either a low power or high power mode. These communication modes will be capable of both forward and return links consisting of commands, telemetry and full duplex audio for crew missions only. The UHF forward link from ISS to the RLV crew (inside the Crew Transportation Module) is expected to consist of 64 kbps audio and 8 kbps data. The forward data will be encrypted commands from the ISS. The UHF return link form the RLV Crew to the ISS is also expected to consist of 64 kbps audio and 8 kbps data. The return data will be telemetry and status.

The expected RLV UHF characteristics are listed in Table 2. The RLV UHF system will also be able to communicate with predetermined ground sites designed to provide a relay connection to the MCC/ RLVCC upon descent. Upon launch and orbit insertion, the RLV will not utilize the UHF link except for early data communications with the MCC, RLVCC and the launch complex for Flight Termination scenarios. When the RLV approaches and begins to initiate an Approach maneuver towards ISS, it is first necessary to establish and maintain a Space-Space communications link before continuing. Failure to establish a continual UHF link between ISS and RLV automatically results in an aborted approach (ref 1).

Table 2. RLV UHF characteristics

	RLV UHF to ISS
Tx Frequency	414.2 Mhz / 417.1 Mhz
Tx Data rate	64 kbps (audio) 8 kbps (data)
Rx Frequency	414.2 Mhz / 417.1 Mhz
Rx Data rate	64 kbps (audio) 8 kbps (data)

The ISS can utilize both Low and High power modes of its Space to Space Communications System (SSCS) to communicate with the RLV or other vehicles in order to cover operational ranges and to meet data transfer requirements. Like the Space Shuttle Orbiter, the RLV will be configured to provide communications coverage to the ISS when outside the range of the AE. The RLV will utilize a combination of multiple UHF antennas to provide hemispherical coverage patterns about the vehicle. These antennas will be collocated both on the external structure of the RLV (anticipated patch or phased array antennas) and within the internal Cargo Bay area. The internally mounted antennas will be a type similar to those currently being used on the Shuttle-ISS design approach, and are utilized when the Payload bay doors are open.

The goal of the UHF system is to operate with a 3 dB link margin to the ISS in all modes, including some intermittent outage duration. However, it is anticipated that a link margin of 0 dB could provide functional operation between the RLV and ISS.

Capability 2 – Crew Transportation Module Communications to ISS, MCC and RLVCC

The Crew Transportation Module (CTM) design for communications leverages off the design of the Reusable Launch Vehicle (RLV) to supplement communications capability and requirements when the RLV is providing a crew transfer to the International Space Station. During all mission phases when the CTM is contained within the RLV cargo bay, the CTM relies on hard-line interfaces with the RLV avionics for audio and data communications. (Figure 2)

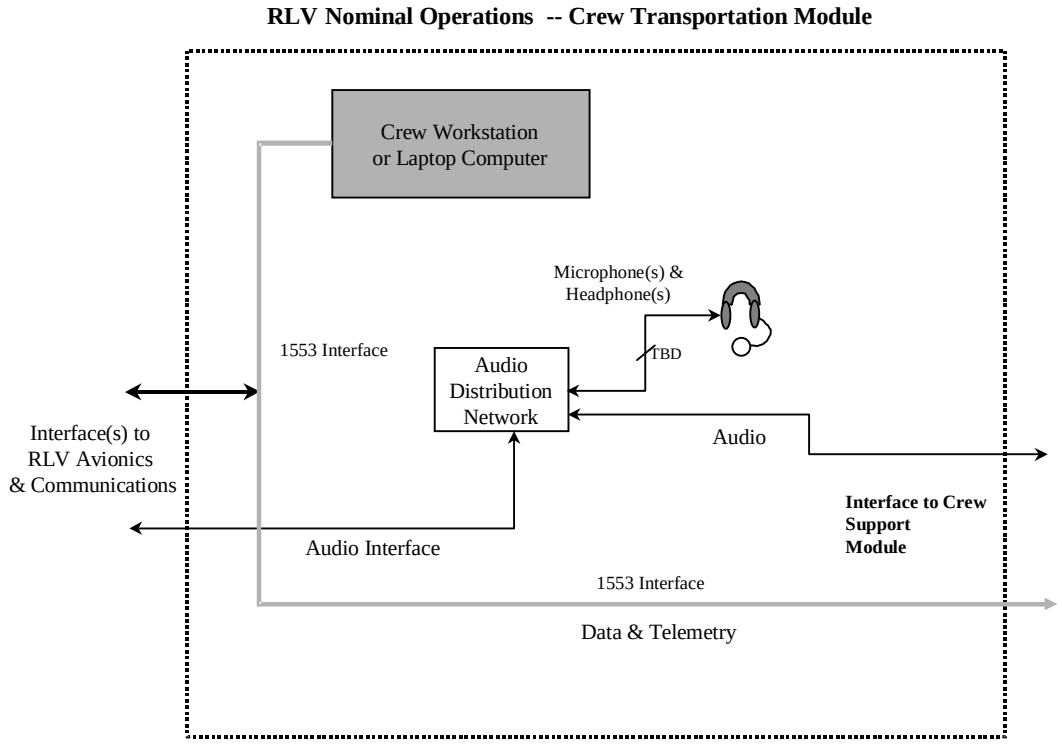

Figure 2. Crew Transportation Module communications

As part of the crew transportation to ISS, the CTM is connected to a Crew Support Module (CSM) which is responsible for the actual connection with the Pressurized Mating Adapter (PMA) on the ISS when the RLV is docking to an ISS NODE. The CSM provides resources and consumables for extended duration while inside the RLV cargo bay, much in the same way that the SpaceHab does for the Shuttle. This CSM also is equipped to provide audio, video and data connections with ISS, MCC and RLVCC via connections to the CTM or with hard-line connections to ISS interfaces. (Figure 3) Communications with the station is accommodated by interfaces routing through the PMA bulkhead connections.

When the RLV is attached to ISS (via CSM attachment), two-way audio between the RLV crew and ISS is accommodated by hard-line interface connections to ISS internal audio bus. (Ref 2) Four sets of twisted, shielded pairs of full duplex audio (plus keying) interfaces provide complete communications between the ISS and the Crew Modules.

Video is also accommodated by hard-line connections to the ISS internal video subsystem. NTSC video can be transferred to the ISS from a coaxial interface (analog) to an ISS Common Video Interface Unit (CVIU) for RLV to ISS video accommodation. A video sync signal is provided by the ISS connection to the RLV (via CSM attachment) to appropriately route the video signal into the ISS video subsystem.

The RLV (CTM and/or CSM) provides a data interface connection between the internal 1553B local data bus architecture and the core ISS data bus. Interface(s) connections to appropriate ORUS within the RLV are located on 1553B bus connections that can be attached to ISS local or control bus interfaces.

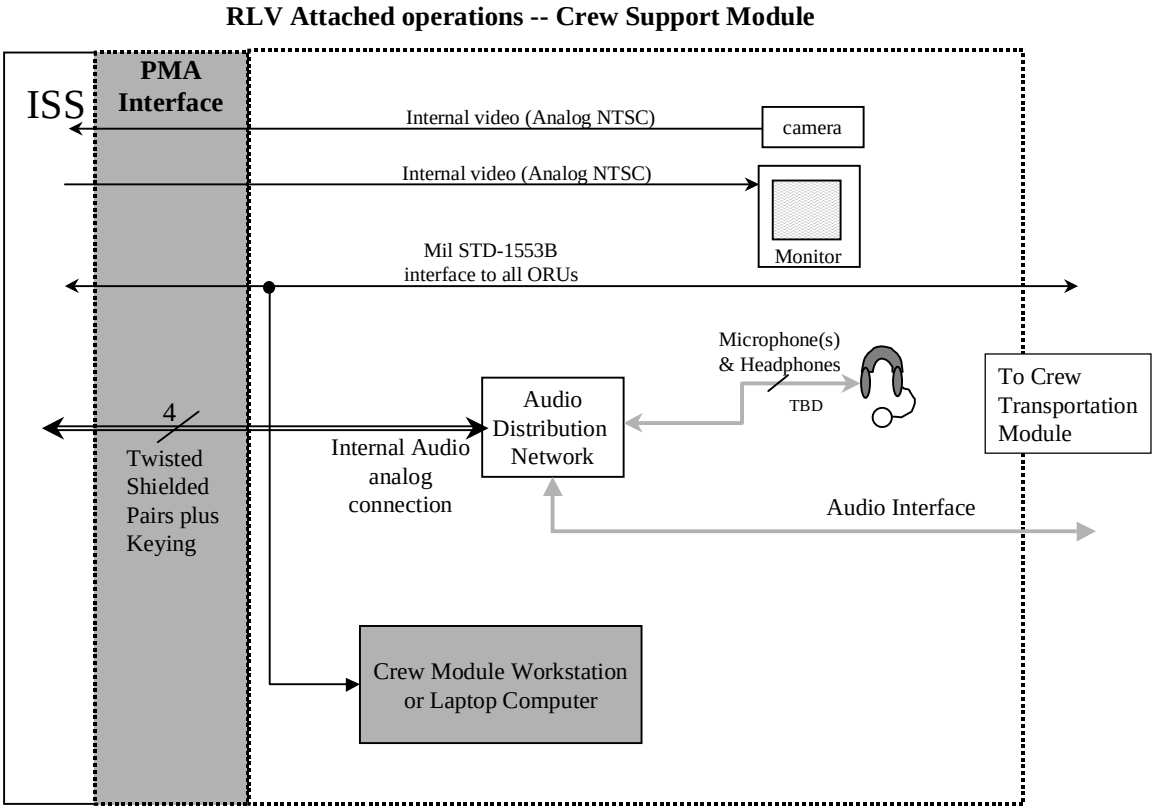

Figure 3. RLV attached communications (audio, video & data)

Capability 3 – Crew Transportation Module Communications to MCC and RLVCC during emergency abort operations

The Crew Transportation Module will be used in cases of emergency where the CTM must depart from the RLV and return to earth. This is considered a rare case where the CTM must eject from the RLV and bring the crew back down to Earth to be rescued. During an abort operation, it is envisioned that the Crew Transfer Module will continue to communicate with the MCC and the RLVCC.

The S-Band subsystem will be active to support initial contact with MCC/ RLVCC (via TDRSS) for critical audio and data transfers during the initial abort sequence. The UHF subsystem will remain active to support contact with ISS (if in range) for audio and data transfers during the initial abort sequence.

Once the CTM approaches atmospheric reentry and the subsequent parachute deployment sequence is executed, the SARSAT subsystem is activated to support initial Search and Rescue beacon signaling. The UHF subsystem remains activated to support Ground contact with MCC/ RLVCC or support ground operations (audio). Activation of a cellular phone system as backup to UHF is also accomplished.

Figure 4 represents a functional configuration of the CTM communications during an Abort Mode of operations.

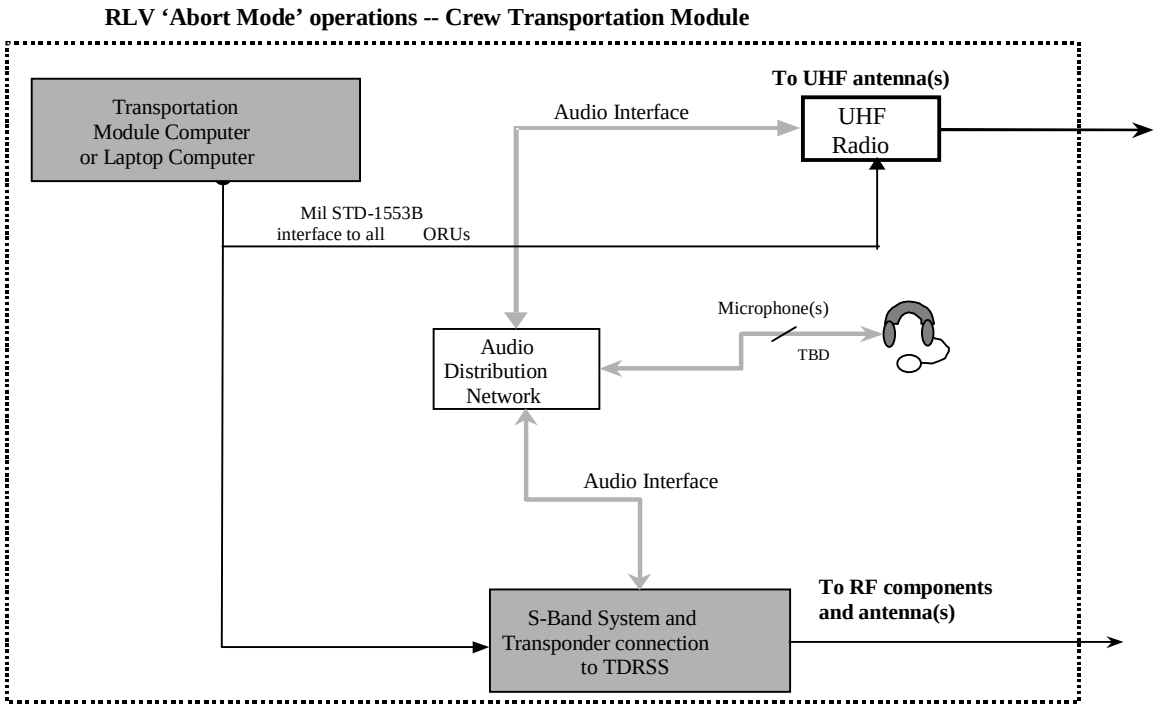

Figure 4. Functional communications for 'Abort Mode'

Conclusion

The Reusable Launch Vehicle will utilize communications systems that are ISS compatible to meet the requirements of a Visiting Vehicle to ISS. Utilizing capabilities that are similar to the Space Shuttle, the RLV will communicate with the U.S. segment of the ISS, and will rely on S-Band and UHF communications to provide full-duplex audio and data communications with ISS, MCC and the RLVCC during crew transfers. The RLV, when attached to the ISS will also communicate through hard-line interfaces to the ISS internal audio, video and data subsystems.

References

1. SSP 50235, Interface Definition Document for ISS Visiting Vehicles, dated January 1998
2. SSP 42018 rev C, ISS US On-Orbit Segment to Ground (Through TDRSS) Interface Control Document
3. JSC 28157, Space to Space Orbiter Radio detailed design document, dated April 1998

Acknowledgements

1. Mr. Joseph Franke, Lockheed Martin Skunkworks, for his support with data and information with respect to the RLV communications approach.
2. Ms. Catherine Sham, NASA JSC, for her support in supplying information about VV concepts and the use of ISS Communications systems.