Operations Methodology for the International Space Station (ISS) High Rate Communications Outage Recorder (HCOR)

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Operational Methodology for the International Space Station (ISS) High Rate Communications Outage Recorder (HCOR)

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Abstract. The HCOR will be used onboard the ISS to record digital data during Ku-band Loss of Signal (LOS) periods. This recorded data will be played back to the ground during Ku-band Acquisition of Signal (AOS) periods. The Data Management (DM) Team at the Payload Operations and Integration Center is the primary operator of this complex recorder. The record and playback capabilities – along with the memory management functions – are presented in this paper. To illustrate how the DM Team plans to manage the record, playback and memory management tasks of operating the HCOR, an operational scenario for a ninety minute orbit is presented.

INTRODUCTION

Onboard the United States Operating Segment (USOS) there are two different communications links – S-band and Ku-band. The S-band system is used to transmit low rate data and to send commands; the Ku-band system is used to transmit high rate digital/video data. Each system has an onboard antenna that transmits data to the ground via a Tracking and Data Relay Satellite (TDRS) in geostationary orbit. In order to transmit data from the USOS each onboard antenna must have line-of-sight with a TDRS. Even though there are several TDRSs positioned in different inclinations available for ISS use, there are periods during every orbit when the onboard antennas cannot communicate with a TDRS. These times are referred to as Loss of Signal (LOS) periods. LOSs are caused by blockage from the earth or from the ISS structure itself. LOSs are also possible because another space vehicle with a higher priority is using the TDRS in view. Because the antennas are located at different locations on the ISS structure, LOS periods for the S-band system and the Ku-band system are often different.

In 1997 a proposal to develop a recording system to capture Ku-band data during LOS periods was accepted by ISS Management. This system includes two different recorders: the Medium Rate Communications Outage Recorder (MCOR) and the High Rate Communications Outage Recorder (HCOR). The MCOR is being designed and developed by Boeing and will serve as an interim recorder until the HCOR is available. The MCOR is a Portable Computer System (PCS) based recorder that uses Commercial off the Shelf (COTS) hardware. It is designed to record up to two channels of data and will be launched in the 5A.1 timeframe. Since only one of the recorders can be configured at a time, the MCOR must be disconnected and removed before the HCOR is installed. The HCOR is the full-capability recorder that is designed to record up to eight channels of data. The HCOR is being designed and developed by Seakr Engineering and will be available in the UF-2 timeframe.

The HCOR is designed to record digital data during Ku-band LOS periods and to playback this recorded data during AOS periods via the Ku-band communications link. This playback is multiplexed together with realtime experiment data and video by the High Rate Frame Multiplexer (HRFM). See Figure 1. The composite HRFM output goes to the High Rate Modem (HRM), then to the Ku-band Antenna Assembly, then to a TDRS Satellite,

then to the White Sands Complex (WSC) ground terminal, then to the Operations Teams at the Marshall Space Flight Center (MSFC) and the Johnson Space Center (JSC), and finally to the Payload Developers (PDs) throughout the world. The current onboard Ku-band system is capable of supporting a downlink of up to 150Mbps. However, the ground system currently has a maximum capacity of 50Mbps. With this constraint the Operations Team will limit the output of the HRFM to 50Mbps. Future upgrades call for modifying the ground system to support 150Mbps.

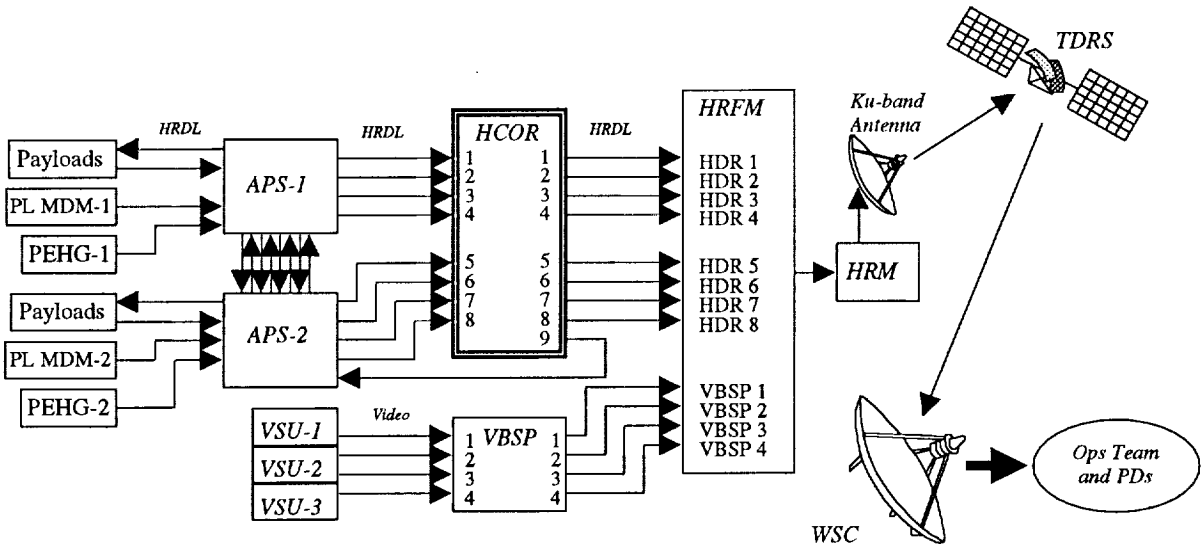

FIGURE 1. Ku-band data flow from onboard data sources to Operations Teams and Payload Developers on the ground.

HCOR RESPONSIBILITIES

The Data Management (DM) Team at the Payload Operations and Integration Center (POIC) – located at the Marshall Space Flight Center (MSFC) in Huntsville Alabama – is the primary operator of the HCOR. The DM Team also nominally manages/commands the Automated Payload Switches (APSs), Payload Ethernet Hub Gateways (PEHGs), HRFM, Video Based Signal Processor (VBSP), Video Switching Units (VSUs), Sync and Control Units (VSUs), and Video Tape Recorders (VTRs). Even though the onboard crew has command capability to these components, all nominal reconfigurations are done via ground commanding from the POIC. The Operations Team at the Johnson Space Center (JSC) is responsible for commanding during the installation/checkout phase and during off-nominal trouble-shooting operations for all of these components. In addition, the JSC Ops Team is responsible for controlling the video system during docking and EVA operations.

HCOR CAPABILITIES

Record

The HCOR has a minimum storage capacity of 220 Gbits. The HCOR can record any combination of the eight High Rate Data Link (HRDL) inputs received via the APSs. The HCOR can receive data from users either as undelimited bitstream or as CCSDS packets. The HCOR, however, can only record data formatted in CCSDS packets; it cannot record data as undelimited bitstream. To record data from bitstream sources, the HCOR first converts the undelimited bitstream data into CCSDS packets. The HCOR can, however, pass-through undelimited bitstream data to the HRFM – but this channel cannot be recorded while in this configuration. When sending a record command the operator must specify a channel mask. The channel mask defines the

combination of input channels to record. The HCOR can record at a maximum of 50Mbps on any given input channel – not to exceed an aggregate rate for all eight channels of 130Mbps. Because the output for all Ku-band data/video cannot exceed 50Mbps, fast record rates (approaching the 50Mbps limit) will not be feasible until system upgrades are completed.

Playback

The HCOR is capable of playing back recorded data on any one or two of the nine output channels. The HCOR can playback from .5Mbps to 95Mbps in .5Mbps increments per output channel – not to exceed an aggregate playback rate for both channels of 130Mbps. As mentioned earlier, all Ku-band data/video cannot exceed 50Mbps. Therefore, playback rates in excess of 50Mbps will not be feasible until system upgrades are completed. When sending a playback command the operator must specify a channel mask plus either a start/stop HCOR Percent Position of recording or a start/stop time of recording. The operator also must specify the playback output port(s) and the playback rate. The channel mask defines the combination of eight input channels to playback. The HCOR output ports can be configured to transmit either pass-through data from the APSs or HCOR playback data – but not both. While in playback mode, the data received from the input port(s) corresponding to the defined playback port(s) is discarded. Output port nine does not feed into the HRFM; it is used to playback HCOR data to APS-2. From APS-2 the playback can potentially be routed to other International Partner (IP) data systems.

HCOR MEMORY MANAGEMENT

Managing the HCOR involves configuring the eight input ports, recording the input port data, playing back the recorded data, and unprotecting the memory once the data is played back to the ground. The four parameters on each of the eight input ports are: Channel Mode, Time Out Value, Application ID (for bitstream users only), and Input Rate. Refer to the document listed in the Reference section for a thorough explanation of these parameters. The data recorded on the HCOR is automatically 'protected' when it is recorded into memory. When memory blocks are 'protected' they are no longer available for use. To free up these blocks the operator must send an 'unprotect' command. To define the memory blocks to 'unprotect' the operator must specify a channel mask plus either a start/stop HCOR Percent Position of recording or a start/stop time of recording.

OPERATIONAL SCENARIO

To illustrate how the DM team plans to operate the HCOR, an example scenario for one orbit is provided. Figure 2 shows the Ku-band AOS/LOS periods and the S-band AOS/LOS periods for a ninety minute period. These times do not reflect actual TDRS predictions; they were generated for this scenario only. Again, the HCOR records digital data during Ku-band LOS periods and plays back the data during Ku-band AOS periods. The S-band coverage is also shown because ground commands can only be sent during S-band AOS. Prior to the start of Segment A, it is assumed that all recorded data on the HCOR has been played back to the ground and the operator has 'unprotected' all memory. Figure 3 shows that the recorder has no protected memory on it prior to the beginning of Segment A. This scenario concentrates on the record, playback and memory management tasks associated with operating the HCOR. It does not, however, show input port configurations or off-nominal events.

To better ensure that the HCOR is properly configured, the DM Team plans to start recording two minutes prior to the predicted Ku-band LOS, and to stop recording two minutes after Ku-band AOS. The DM Team plans to begin HCOR playback of recorded data approximately three minutes after Ku-band AOS. Additionally, the DM Team will only attempt to playback the HCOR if the Ku-band AOS period is greater than ten minutes. During Ku-band AOS periods shorter than eight minutes DM will configure the HCOR to continue recording through the AOS period. The DM Team will modify these constraints as needed during operations.

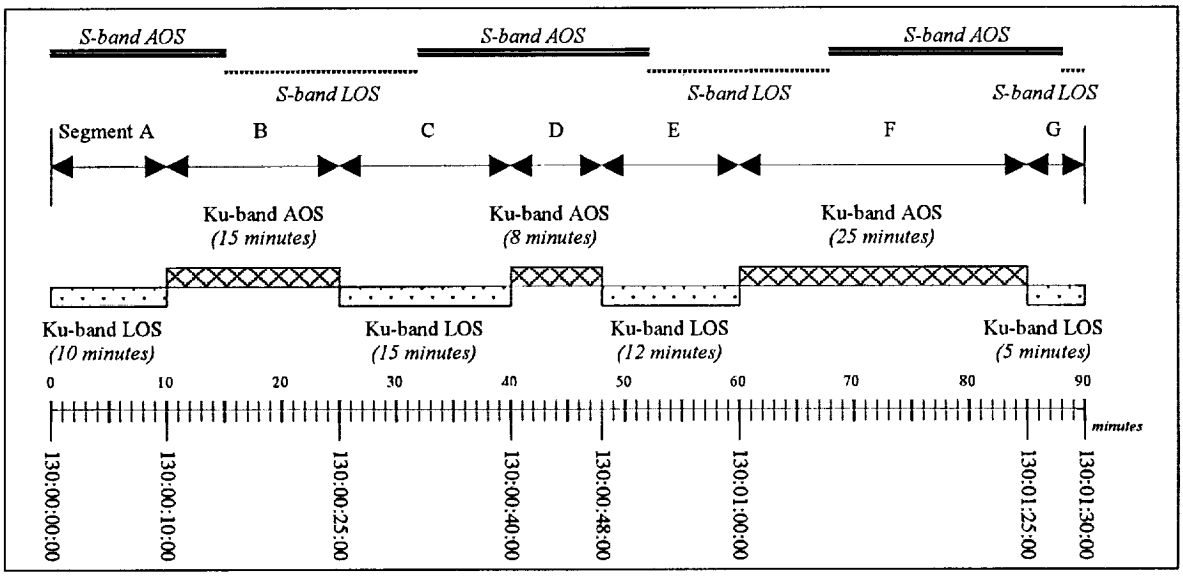

FIGURE 2. Example of 90 minute orbit showing Ku-band and S-band AOS and LOS periods.

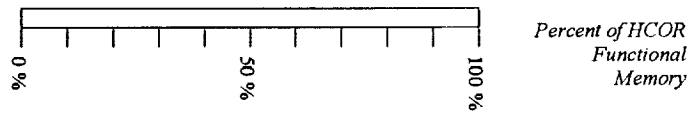

FIGURE 3. Illustration showing HCOR protected memory prior to Segment A.

Segment A

Segment A is a Ku-band LOS period that starts at 130:00:00:00 *(day:hr:min:sec)* and lasts for ten minutes (see Figure 2). For this segment it is assumed that all eight input channels need to be recorded. Two minutes prior to going Ku-band LOS the operator commands the recorder 'on' with a channel mask = 1, 2, 3, 4, 5, 6, 7, 8. Since the ISS is S-band AOS at this time, this series of record commands can be sent in realtime. The HCOR records each input channel selected at the bandwidth rate setting for that particular input port. The HCOR cumulative record rate, therefore, is the sum of all input channel rates selected in the channel mask.

Segment B

Segment B is a Ku-band AOS period that starts at 130:00:10:00 and lasts for fifteen minutes. Two minutes after coming Ku-band AOS the operator terminates HCOR recording with a 'record off' command. Figure 4 shows that the recorded data from Segment A is from 0% to 20% on the HCOR. The HCOR now has 20% of HCOR Functional Memory that is protected. Approximately three minutes after coming Ku-band AOS, the operator initiates an HCOR playback. For this playback it is assumed that all eight of the recorded input channels need to be played back. The operator commands the recorder to 'playback on' with a channel mask = 1, 2, 3, 4, 5, 6, 7, 8. The operator must also specify the HCOR playback output port(s), the playback rate, and either the playback

start/stop HCOR Percent Position of recording or the start/stop time of recording. For this case the operator specifies the start/stop HCOR Percent Position of recording as 0% to 20%. Additionally, the operator specifies

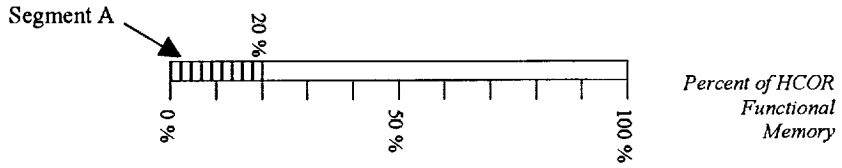

FIGURE 4. Illustration showing HCOR protected memory after recording Segment A.

output port one as the playback channel. Recall, since HCOR output one going into HRFM port one carries the HCOR playback, the data routed from the APS into HCOR input port one is discarded. Data from the APSs into ports 2, 3, 4, 5, 6, 7 and 8 passes through to the corresponding HRFM channel simultaneously while playing back HCOR data on channel one.

Since the ISS is S-band AOS at this time (see Figure 2), this series of playback commands can be sent in realtime. Once the playback begins, all recorded channels specified in the channel mask begin outputting on HCOR output one. Playback begins at the start value of 0% for this case. Realtime telemetry from the HCOR indicates the Percent Position during the playback. Assume that toward the end of the playback period the telemetry indicates the playback is at 18% HCOR Percent Position. The operator notes this for future use. The operator terminates the HCOR playback with the 'playback off' command. The HCOR protected memory is still as shown in Figure 4. Even though from 0% to 18% was played back, the memory from 0% to 20% is still protected until an unprotect command is sent.

Segment C

Segment C is a Ku-band LOS period that starts at 130:00:25:00 and lasts for fifteen minutes. It is assumed that only input channels 5, 6, 7 and 8 need to be recorded during this segment. Two minutes prior to going Ku-band LOS the operator commands the recorder 'on' with a channel mask = 5, 6, 7, 8. Since the ISS is S-band LOS, these commands (along with the previous 'playback off' command) cannot be sent in realtime. They must be sent from the ground as Time Tagged Commands prior to going S-band LOS at 130:00:15:00. These Time Tagged Commands are sent to the Command and Control Multiplexer/Demultiplexer (C&C MDM) onboard with an associated execute time. At the specified time the HCOR commands are executed.

Segment D

Segment D is a Ku-band AOS period that starts at 130:00:40:00 and lasts for eight minutes. Two minutes after coming Ku-band AOS the operator terminates HCOR recording with a 'record off' command. Figure 5 shows

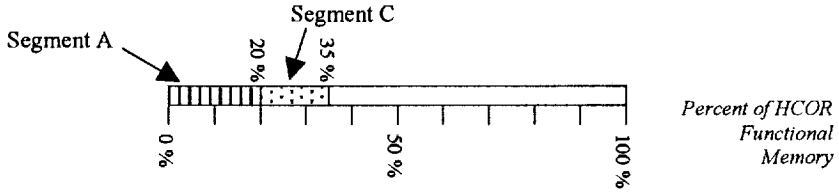

FIGURE 5. Illustration showing HCOR protected memory after recording Segment C.

that the recorded data from Segment C is from 20% to 35% on the HCOR. The HCOR now has 35% of HCOR Functional Memory that is protected. Because the Ku-band AOS period is less than ten minutes, the DM Team does not attempt to playback HCOR data. While Ku-band AOS, data routed from the APSs into all eight ports passes through to the corresponding HRFM channel for realtime downlink.

Sometime during this period the DM Team verifies that the earlier playback of Segment A data from 0% to 18% was received successfully on the ground. At this point this HCOR memory segment can be unprotected. The operator sends the 'unprotect' command with a channel mask = 1, 2, 3, 4, 5, 6, 7, 8. The operator must also specify either the start/stop HCOR Percent Position of recording or the start/stop time of recording to unprotect. For this case the operator specifies the start/stop HCOR Percent Position as 0% to 18%. Since the ISS is S-band AOS at this time (see Figure 2), these unprotect commands can be sent in realtime. Figure 6 shows how segments A and C shift down by 18% following the unprotect command.

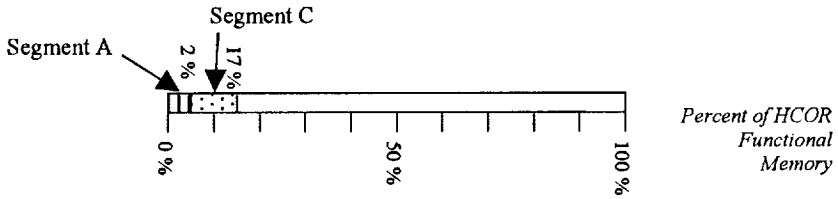

FIGURE 6. Illustration showing HCOR protected memory following unprotect command.

Segment E

Segment E is a Ku-band LOS period that starts at 130:00:48:00 and lasts for twelve minutes. It is assumed that all eight input channels need to be recorded during this segment. Two minutes prior to going Ku-band LOS the operator commands the recorder 'on' with a channel mask = 1, 2, 3, 4, 5, 6, 7, 8. Since the ISS is S-band AOS at this time, these commands can be sent in realtime.

Segment F

Segment F is a Ku-band AOS period that starts at 130:01:00:00 and lasts for twenty-five minutes. Two minutes after coming Ku-band AOS the operator terminates HCOR recording with a 'record off' command. Figure 7 shows that the recorded data from Segment E is from 17% to 29% on the HCOR. The HCOR now has 29% of HCOR Functional Memory that is protected. Approximately three minutes after coming Ku-band AOS, the operator initiates an HCOR playback. For this playback it is assumed that all eight of the recorded input channels need to be played back. The operator commands the recorder to 'playback on' with the output on port

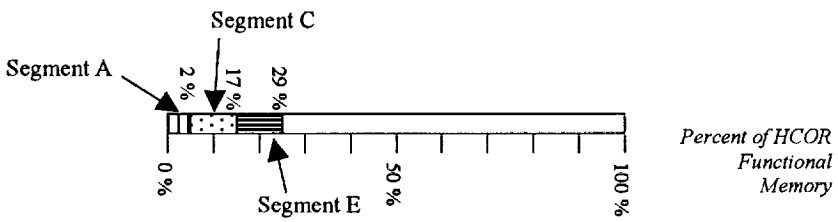

FIGURE 7. Illustration showing HCOR protected memory after recording Segment E.

eight. Even though Segments A and E sampled channels one through eight – while Segment C sampled only channels five through eight – the operator uses a channel mask = 1, 2, 3, 4, 5, 6, 7, 8. If the operator, for example, specified a playback channel that was not sampled in any of the protected segments, the command would still be valid. There would simply not be any data played back for that unsampled channel. For this case the operator specifies a start/stop HCOR Percent Position as 0% to 22%. This is the estimated amount of data that can be played back during this Ku-band AOS period. These values are dependent on the amount of data on the HCOR that needs to be played back and the rate of the HCOR playback – the greater the playback rate the greater the quantity of data that can be dumped during a given Ku-band AOS period. Once the HCOR begins playing back on port eight, the data routed from the APS into input port eight will be discarded. Data from the APSs into ports 1, 2, 3, 4, 5, 6 and 7 will pass through to the corresponding HRFM channel simultaneously while playing back data on channel eight. Since the ISS is S-band LOS at this time, these commands (along with the previous 'playback off' command) cannot be sent in realtime. They must be sent from the ground as Time Tagged Commands prior to going S-band LOS at 130:00:52:00. See Figure 2.

Realtime telemetry from the HCOR indicates that the HCOR playback completed from 0% to 22%. The HCOR protected memory is still as shown in Figure 7. Even though from 0% to 22% was played back, the memory from 0% to 29% is still protected until the unprotect command is sent. At this time DM verifies that the preceding playback was successfully received on the ground. The operator then sends the unprotect command with a channel mask = 1, 2, 3, 4, 5, 6, 7, 8. The operator also specifies the start/stop HCOR Percent Position as 0% to 22%. Since the ISS is S-band AOS at this time, these commands can be sent in realtime. Figure 8 shows how all segments shift down by 22% after the unprotect command. Segment E is the only protected segment remaining in memory.

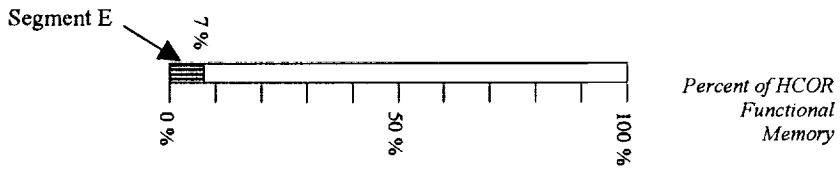

FIGURE 8. Illustration showing HCOR protected memory following unprotect command.

Segment G

Segment G is a Ku-band LOS period that starts at 130:01:25:00 and lasts for five minutes. It is assumed that all eight input channels need to be recorded during this segment. Two minutes prior to going Ku-band LOS the operator commands the recorder 'on' with a channel mask = 1, 2, 3, 4, 5, 6, 7 and 8. Since the ISS is S-band AOS at this time, these record commands can be sent realtime. The recorded data from Segment G is from 7% to 15% on the HCOR.

CONCLUDING REMARKS

This scenario concentrated only on the record, playback and memory management functions of operating the HCOR for a single orbit. Even so, it shows some of the complexity of managing the HCOR. Of particular concern to the DM Team is the fact that commanding windows (S-band AOS periods) frequently do not match Ku-band AOS/LOS transition periods – the periods the operator will have to configure the HCOR. This will require the operator to extensively use Time Tagged Commands. It will also significantly hinder the operators ability to handle changes in realtime. For example, to effectively utilize every playback opportunity, the DM Team plans to use Time Tag Commands to playback the HCOR during periods with Ku-band AOS and S-band LOS. During these periods the operator cannot modify or stop the HCOR playback in realtime.

The HCOR is capable of playing back and unprotecting a small number of recorded channels. Using these capabilities, however, would make memory management extremely complex – at best. For this reason, DM plans to nominally playback all recorded channels in a first-in, first-out basis. Additionally, unprotect commands are illegal while the HCOR is in record or playback mode. Because the HCOR will be in one of these modes most of the time, DM plans to nominally unprotect all eight channels (over the range successfully played back) immediately following each playback.

This scenario also illustrated how DM plans to simultaneously downlink and record experiment data for several minutes on either sides of Ku-band AOS/LOS transitions. Each Payload Developer will receive some experiment data twice – once during realtime and again during HCOR playback.

ACKNOWLEDGEMENTS

The author would like to thank.....

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