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EAGLE-1

EAGLE-1 – Questions and Answers

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1. Introduction ... 4

1.1 Purpose and Objectives ... 4

1.2 Document Structure ... 4

2. Reference Documents ... 5

2.1 Reference Documents ... 5

3. Workshop Q&A ... 6

4. Additional questions ... 14

List of Tables

Table 1: Document Structure ... 4

Table 2: Reference Documents ... 5

1. Introduction

1.1 Purpose and Objectives

This document aims to provide answers to questions that were asked during the *From Science to Application* workshop held on 2024-11-27, as well as to other questions that were received by SES in the following weeks.

New issues of this document will be published as new questions and corresponding answers become available.

1.2 Document Structure

This document is structured according to the following chapters.

Table 1: Document Structure

Section	Title	Description
1	Introduction	Introduction of the present document
2	Applicable and Reference Documents	Listing of all the Applicable and Reference Documents
3	Workshop Q&A	Questions that were asked during the *From Science to Application* workshop held on 2024-11-27, with corresponding answers
4	Additional questions	Additional questions received by SES concerning the publicly available documentation, and corresponding answers

2. Reference Documents

2.1 Reference Documents

The following documents are made reference to in the document.

Table 2: Reference Documents

Reference	Document Number and Title	Version	Date
[RD01]	EAGLE-1 Optical Free Space Interface Control Document (ICD) for the European Commission (EC)	E	2024-12
[RD02]	OGS Requirement Specification for the European Commission	1.0	2025-04
[RD03]	EAGLE1-00149-SYS-SPC-FAU_QKD Protocol Design Definition File for EC	1.0	2024-02-16
[RD04]	EAGLE-1 Protocol presentation: From science to application	1.0	2024-11-07

3. Workshop Q&A

1. In the protocol presentation, the post processing requirement was to detect enough signals in both bases. However, it is not stated how one chooses the "test" set. Can you comment on this?

The number defining how long to collect signals on ground is the finite size block size. It is defined as 16.5 x 10^5 Qbits per base. This means that QKD signals are gathered (potentially for several overflights) on ground until this number is reached before the raw key is processed to obtain the final key via the error estimation and privacy amplification steps in the QPS. Sifting and error correction are done before on smaller blocks. Note that this gathering and all other QKD processing is handled in the QPS; the receiver just needs to perform time synchronisation (c.f. second talk) and send the detected signals to the QPS via the UDP interface.

2. On page 15 of the QKD protocol presentation [RD04]: if the QKD signal is strong enough, can the state be sent to both basis measurement paths at the same time? (through the first beam splitter). Are clicks like that then excluded by the QPS?

In principle it can happen that several channels click simultaneously. In this case, all clicks are reported to the QPS which will handle this case according to the security proof. One more comment on this: In contrast to what is stated in the question such cases can never stem from one and the same quantum signal as the sent mean photon number in the quantum states is always <1. They rather appear if a background or dark counts appears coincidently to a quantum signal click by chance. However, this is in general very rarely the case for the Eagle-1 protocols parameters.

3. QPS (namely the selected error reconciliation protocol) are out of scope for this talk, or can you share some info about that?

The QPS is out of scope of the talk. The project partner responsible for the QPS is the Austrian Institute of Technology (AIT) who have published a lot on that topic in their body of work. The Eagle-1 software was built upon this long-term heritage. It was combined with the security proof developed by Palacký University Olomouc (UPOL) mentioned in the talk and the overall protocol concept developed by FAU/MPL. However, the specific Eagle-1 solution is not published.

4. Do you use PM fibre in the interferometers. How do you correct automatically the polarization state of the incoming pulses?

Yes, we use PM fibres. As stated in EAGLE1-00149-SYS-SPC-FAU_V1.0_QKD Protocol Design Definition File for EC 20240216 (publicly available) in the interface definition, the light shall already be coupled in PM fibre with the PER specified in there. This can be guaranteed with a suitable feedback loop.

5. What is QPS standing for again?

QPS stands for “QKD Processing Software”.

6. Does a lower detector dead time help with the synchronization and clock recovery as well? Or is only useful for faster quantum key recovery?

For the quantum states, the detector dead time is no limit at all as the count rates there are low due to the high losses. The dead time is only relevant for the bright reference states. However, for the protocol as it is designed now, a lower dead time would not help to increase the performance of the time synchronization and clock recovery as the time scales of the reference pulses are chosen such that they match with the 80ns. Having a lower dead time would in principle allow to send more states in the same amount of time.

EAGLE-1 – QUESTIONS AND ANSWERS

7. Are these different synchronization steps all done in post-processing?

Yes. The raw signal in the receiver is consisting of time stamps.

8. Is the time synchronization scheme implemented and handled by the QPS, or will it need to be applied before pushing the received clicks to the QPS?

It needs to be applied before the QPS and is part of the quantum receiver system.

9. It was mentioned that the approach of eagle is to rely strongly on well-established communication technologies, yet the presentation sessions describe in detail a tailored engineering approach. How are technological maturity and experimental novelty balanced?

Even though the protocol itself is new and tailored to the satellite QKD problem, the employed hardware, electronics and their controlling is to a large extent the same as it is used in classical communication solutions. With TESAT Spacecom and DLR (among others), we have strong partners with a lot of experience in classical communications which is very useful in developing and building a system capable to employ the presented QKD protocol. By that, we profit from this experience in mature technology.

10. How robust is the phase protocol quantum Tx/Rx with respect to atmospheric turbulence, is there heritage flight data available and/or need identified to adapt to changing conditions? What are the formal requirements to gain access with a custom OGS to interaction with collaborative satellite transmitter? Any recommendation for best practice for receiver development and implementation (tools, technologies, etc)? What are requirements for RNG?

As atmospheric influence appears on kHz time scales whereas we are sending in the GHz regime, no influence is expected. In terms of heritage, there is no phase encoding satellite QKD mission yet that we could learn from (as we are the first one). However, (as mentioned in question 9) classical satellite communication relies on phase encoding as well, facing a lot of challenges parallel to our application. From that we can learn. As reference, one can for example look at the body of work from TESAT Spacecom on that topic (e.g. here https://doi.org/10.1117/12.2218275) or our dedicated measurements investigating quantum noise properties of phase encoded satellite signals (https://doi.org/10.1364/OPTICA.4.000611) or other groups (e.g. https://doi.org/10.1103/PhysRevLett.116.253601).

Any OGS that is going to be used to connect to EAGLE-1 will need to follow a network certification which the framework will be detailed. The requirements are to be published.

For the quantum receiver, no (Q)RNG is required (c.f. slides). The question on best practice is difficult to answer in general. One should have some experience with classical and/or quantum communication and fibre optics.

11. How do we deal with link loss caused by two successive photons from two successive pulses that both need to reach the receive aperture? A link loss of e.g. 30 dB is then converted into a 60 dB loss. Why does that not disable the whole concept?

There are no two photons, as the quantum state is defined as the whole 400ps time slot. In the whole time slot the mean photon number is <1. Thus, we are dealing with single photon interference.

12. The 7 dB losses for the receiver include the detector's efficiency?

Yes, the detector efficiency is included in the 7dB.

13. In case this question is seen later: is the 75 Hz background light/dark count rate limitation before or after temporal filtering?

The 75Hz are before temporal filtering is applied.

14. Are there publicly available specs related to the optics, in order to design adequate receiving telescopes / ground stations?

There are some documents related to the ground station that are publicly available here:

https://ses-techcom.com/download-category/eagle-1-documents/

A detailed building instruction/blueprint for the quantum receiver is out of the scope of this workshop.

15. Which are the Test Cases that you used to validate the System Requirements listed in one of the last slides?

The test cases need to be defined as part of the design, development and building process of the quantum receiver. In general, tests have to be done with sending sources. Depending on the parameter that shall be tested this can be a CW laser, a suitable pulsed laser, a fake sending module or a real sending module (c.f. questions 16).

16. Is there a way to test on the ground a receiver designed by someone else with the EAGLE-1 transmitter? how can compatibility be guaranteed via test without doing in orbit tests?

SES is currently planning to offer a validation service for third parties QKD Receiver. The details on how this will be organised and costed will be provided at a later date.

17. Could you please provide a more detailed rationale behind the requirement of max 7dB losses in the optical receiver? thanks!

For the QKD performance the overall end-to-end losses are relevant. Those can be divided into channel loss, ground station loss before the quantum receiver and loss in the quantum receiver. The optical losses of 7dB for the quantum receiver are resulting from trading-off all contributions carefully and also taking into account technical feasibility.

18. How does the intensity of pulses vary (numb of photons per pulse)? What is the probability that the two pulses of a quantum pulse pair both reach the OGS aperture? For link budgeting purposes, we assume a beam waist of 4 cm on the space terminal, is this correct?

The intensity of the sent states is defined in the slides for the different parts of the frame. On ground, single clicks are detected depending on the mean loss and its fluctuation.

As the mean photon number in one quantum state is <1, there are no two photons in one state (c.f. questions 2 and 11).

All information publicly available on the free space interface can be found in the documents to be found here:

https://ses-techcom.com/download-category/eagle-1-documents/

EAGLE-1 – QUESTIONS AND ANSWERS

19. Why single mode polarization maintaining fibre in Rx if it is phase only in QKD?

For the employed relative phase encoding, we interfere the two pulses. For that, it is important that the visibility of the interference is high and noise is low. Both parameters are influenced by polarization. Thus, polarization needs to be controlled to the extent defined in the slides.

20. What is the average number of photons in a quantum pulse (is it 1)?

The mean photon numbers are defined in the slides.

21. What is included in the ""maximum optical loss receiver""? Does it include the ground optical telescope, the single-mode optical fiber coupling (adaptive optics loss), the optical losses in the quantum receiver itself? What are the requirements for the spatial mode? It is required to have single-mode optical coupling, or can you also handle free-space optical coupling? Do you have a detailed definition?

The maximum optical loss of the receiver is all the loss after fibre incoupling (coupling loss is not included) up to photon detection (detection efficiency is included, c.f. question 12). The 3dB protocol loss are not included here as those are applied in software in the post-processing (discarding side peak slots).

In principle, we see no fundamental reason against a free space quantum receiver fulfilling the requirements. However, for different reasons (e.g. having a stable, integrated system and a natural spatial background light filter through fibre coupling) we developed a fibre-based setup. Thus, there might be unforeseen problems or challenges in a free space solution that we do not foresee now without having thought through such a design completely.

A detailed building instruction/blueprint for the quantum receiver is out of the scope of this workshop.

22. Taking the bright pulse transmit power of 4.2 µW with a pulse duration of 80 psec, a Tx aperture of 80mm, a Rx aperture of 800mm and a link distance of 945km (30 degrees elevation), yields 3.1 photons per pulse from the link budget, which is not very bright. No mis-pointing and no atmospheric or instrumental attenuation is assumed. The link attenuation calculated is: -29.4dB. Is that correct?

Concerning the received light of the bright reference pulses, two numbers are important:

- The minimum number of photons that needs to be received. This number is 0.01 photons per bit for frame number decoding (c.f. slides 57/58 second talk)
- The maximum number of photons acceptable. This number depends on the exact detection system that is used (SNSPD system)

The expected intensities depend on the exact conditions of the ground station that is employed (location, ground station loss etc.). Taking these conditions into account the minimum number of photons needs to be assured.

All information publicly available on the free space interface can be found in the documents to be found here:

https://ses-techcom.com/download-category/eagle-1-documents

23. The 3dB that are lost due the side photons are used for intensity calculations at the security proof? or are they really useless?

The side peak photons are not used in any security proof calculations. They are used as (non-interfering) intensity measurement to stabilize the losses from the interferometer outputs up to the photon detection (c.f. slide 39 first talk). However, they are not used for key generation.

In the proof itself, there is a specification for the detection efficiency mismatch (c.f. slides 49/50 first talk) on ground. This can in principle be also specified without having the stabilization loop in place. Both will be investigated in the demonstration.

24. How to you handle the fact that sometimes not all of the bright pulses are received? Are you still able to recover the start sequence?

Yes, we are. For details, we refer to the slides of Conrad Rößler's talk "The Eagle-1 time synchronization scheme.

25. Are possible intensity correlations considered in the security proof?

No, intensity correlations are not part of the proof. We try to avoid them by implementation as good as possible. This is a topic not to be considered in the demonstrator, but in a security upgrade of the system e.g. by including them in the proof.

26. Have you implemented any mechanisms to deal with the doppler effect?

Yes, we have. For details, we refer to the slides of Conrad Rößler's talk "The Eagle-1 time synchronization scheme"[RD04].

27. How is the randomness created at the sender (Tx)? Why don't you filter all the out-of-band signal with 120dB?

There is a QRNG on the sending side.

The filter specifications are also driven by technical feasibility (it is already challenging to produce a filter with the requirements specified here). However, in principle it does not hurt to filter more. So, the suppression ratios can be considered minimum requirements.

28. How is the communication between the ground station and the satellite organized and how is the data exchange coordinated? How is the QR feedback sent back to the satellite, as to which photons have been received or lost, etc? Describe the mechanism. Is there an ICD that describes the communications exchange?

The classical communication is handled via an optical up- and downlink. The whole communication process is handled by the QPS interfacing this link. For the quantum receiver only the time synchronization as described in talk 2 has to be performed and the data has to be sent via UDP to the QPS. The exact datagram will still be released.

Concerning the ICD, there are some documents related to the ground station that are publicly available here:

https://ses-techcom.com/download-category/eagle-1-documents/

29. Please provide an overview of the polarization compensation expectations on the ground receiver.

see answer question 4

30. Please specify the (minimum) bandwidth requirement for the four SNSPDs.

The minimum bandwidth requirement is the passband of the entrance filter (see "Quantum channel" on slide 18 of first talk). However, usually the bandwidth of SNSPDs is much broader.

31. Regarding phase locking of the interferometers, it seems that the detector to measure the phase must be single photon detectors. If this is the case, are 79 pulses enough to characterize the phase to the accuracy needed to keep the QBER low enough? Which is the target accuracy and the target QBER? Moreover, as the system will most likely not use photon number counting detectors, is there a possibility to have a biased value when the mean photon number per pulse at the receiver is close to 1? Has this effect been considered, also in relation to the channel fading? Same question (are 79 pulses enough) for the calibration of the VOAs

As detailed in [B. Hacker et al 2023 New J. Phys. 25 113007] the locking algorithm (as well as the VOA algorithm) works on larger time scales than just one frame. Several frames, and by that their respective bright reference states, are gathered to reach the required accuracy (this needs to be traded-off against the desired locking frequency). The target QBER depends on more factors than just phase jitter and has thus to be analysed for the overall system. However, the target phase jitter value that shall (and can) be reached with the phase locking algorithm is specified as $\pi/50$ (see slide 56 first talk). Mean photon numbers close to or above 1 are no problem.

32. The bandpass of the receiver filter is 0.2 nm. Has a stability test of the transmitter laser been performed to ensure the emission frequency will remain within this range with operational temperature, pressure, and ageing of the device?

Yes, the bandwidth requirement is aligned with the sending laser specifications.

33. The intensity of the quantum signal needs to be kept within a certain interval. Which are the methods to guarantee that? Is a calibration detector foreseen and in case, in which document is the strategy described?

Keeping the mean number fluctuations at the level specified in the slides is handled at the transmitter and not subject of this workshop. On ground no specific care needs to be taken on these fluctuations.

34. During the presentation, a method to recover from Doppler effects was presented. This method covered how the sync is affected and how it can be recovered. However, as far as I understood, there was no discussion about how the Doppler effect affects the visibility of the interferometer. To the best of my knowledge, the Doppler introduced by a satellite will shift the phase of consecutive pulses, making this phase difference effectively random. Some papers address this by simply waiting for that phase difference to be 0 or small, processing only those counts, but this introduces big losses. Other works I’ve seen calculate which shift this is going to be and pre-compensate it by fine-tuning the laser temperature, although this looks difficult and would introduce complexity in the satellite. I would like to know what your approach is to deal with this problem. Thanks

Apart from the time synchronization aspects of the Doppler effect covered in the second talk, there are indeed also optical effects related to the Doppler effect. On the one hand, there is a shift of the wavelength which is auto compensated by using the reference pulses which are temporally multiplexed to the quantum signals. On the other hand, the phase might indeed be changed in principle. Here one needs to look at the frequencies of the effects: to influence the relative phase within a pulse pair seriously, phase changes needed to occur in the GHz range (as the two pulses have a temporal distance of 160ps). However, the Doppler effect is much slower leaving the relative phases undisturbed.

35. Can you please also specify the (minimum) electrical bandwidth of the SNSPDs?

The electrical bandwidth is related to the timing jitter. A typical value would be 15ps (FWHM) resulting in an electrical bandwidth of 0.44/15ps = 29.33GHz (3dB).

36. Do we need any more driver to support KMS with our testbed or other testbed? Specially in DV QKD. (KMS support)

The question is unfortunately not clear to us. If this is still relevant, please contact us on contact-EAGLE-1@ses.com so we can clarify it together.

37. Are SNSPD detectors needed, or would SPADs work as well?

SNSPDs are usually the detectors of choice for satellite QKD as they can provide high efficiency while having low dark counts at the same time. However, in principle also other single photon detectors can be used as long as the requirements are met.

38. What are the system requirements for the provided system software? Can it run on MS Windows (10, 11 etc), or on Linux as well. How powerful should be the PC?

The software will run in a Linux based environment. The actual specification will be issued in a later version of the documentation available on our website

39. The 75 Hz limit for background light + dark counts seems very restrictive. What would happen to the key distribution if the SNSPDs had a DCR of, say, 150 Hz?

Ultimately, this depends on all system parameters like link budget, detection error rate of the receiver and timing- and phase jitter which in turn depend on the concrete implementation. Depending on that, it could be possible that more background counts can be supported. The value of 75Hz is what works well with the other parameters given in the slides.

40. How many ground stations can communicate with Eagle-1 during one night in Europe? I suppose that during one pass it can communicate only with one, or maybe more?

The EAGLE-1 satellite can perform multiple QKD contacts per night. The exact number of possible QKD contacts however also depends on the location of the OGS in relation to the satellite orbit. Only one OGS can be served at a time. During one overflight over Europe in most cases only one OGS is served due to the limited overflight time.

41. Would you provide post-processing IP core? or at least requirements?

The time synchronisation and phase locking software has to be implemented as part of the quantum receiver design efforts.

42. We discuss about the Quantum Receiver but the Post processing was not discussed. Can you provide more information on the requirements?

Post processing is covered in the QPS. More information will be provided later. Concerning details of its implementation we refer to question 3.

43. It is evident that using a PM fibre can simplify the implementation of the QKD receiver, as demonstrated in the scheme presented by Bastian Hacker et al. (2023, New J. Phys. 25, 113007). However, alternative QKD receiver designs for phase encoding, which utilize non-PM single-mode fibres at the input, are also reported in the literature. Are these alternative designs permissible for constructing the QKD receiver, even if the requirement for polarization-maintaining coupling is not fulfilled?

In principle, also non-PM fibres can be used as long as the visibility and stability requirements can be fulfilled.

44. Can you share your thoughts on additional QKD Protocols like BBM92? Many thanks for these valuable sessions.

In general, there are many QKD Protocols that one can think about designing a system. Our main drivers behind our choice of BB84 decoy with relative phase encoding are summarized on slide 4 and 5 of the first talk. Commenting on entanglement-based schemes like BBM92: entanglement based schemes (in contrast to prepare and measure schemes) have the advantage that the trusted sender assumption can be dropped. However, the current performance of entanglement sources, and in consequence the resulting QKD performance, is not good enough that a satisfying performance for an operational system can be achieved. Furthermore, having an entanglement source in space poses a lot of additional technical challenges on the satellite.

45. Regarding the error correction inefficiency parameter: on the slides it's 1.5, but isn't that quite high? Can you provide more info on the protocol used (Cascade, LDPC, etc.) and how you got 1.5?

The error correction inefficiency parameter of 1.5 is a worst-case value, depending on the error rate it might be better for certain error correction blocks. In order to be conservative only the worst-case value was given. Concerning details of the QPS implementation we refer to question 3.

46. In your presentation you spoke about a QKD receiver design based on PM fibers. Does it mean that you expect the OGS to make sure that the QKD signal's polarization is aligned with either the slow or the fast axis of the PM?

Yes, the OGS incoupling needs to couple the QKD signal onto one of the axes of the PM.

4. Additional questions

47. In the "EAGLE1-00149" document on page 6 it is said that "*The Optical Ground Station shall offer sufficient background light suppression to limit the background light*

- ***to less than 1800 Hz (photons per second) or -126.4 dBm with max. 800 Hz (photons per second) or -129.9 dBm in the Quantum channel In-band***
- ***(1565.495864nm ± 5nm) max. 1000 Hz (photons per second) or -128.9 dBm in the Quantum channel out-of-band*"**

What does this mean? The applied filters should filter out the background so much? Where are these values measured? Before the detectors?

However, there is another statement about the background photon flux in the document (slides) "The-Eagle-1_QKD_protocol.pdf" In the "Background light" table is is said: "*Upper limit receiver detector background counts per detector : 75 Hz*" The 75 Hz is much less than 1800 Hz, how to interpret the 75 Hz background at the detector?

The background counts (1800) are measured at the entrance of the QKD receiver, after the filter whose specifications are provided in Slide 18 of the “The Eagle-1 QKD protocol” is applied. The OGS needs to perform filtering and can rely on said filter to take the straylight level down to required levels. These values don’t account for intrinsic dark counts at the detectors, but they only account for external sources (including straylight from classical optical downlink and uplink channels).

This value (75 Hz) is the maximum allowed background count rate per detector, obtained from the initial 1800Hz rate as follows:

1. Multiplying the rate by the loss budget of the QKD receiver (max 7 dB).
2. Dividing the result by the number of detectors (4).
3. Adding the intrinsic detector dark counts.

This number has been taken with some margin and can slightly change, depending on the actual loss budget of the OGS (better loss budgets allow for higher background counts).

48. *Referring to “The-Eagle-1_QKD_protocol”*

a) **When you refer to "high losses" up to 60 dB you do include the QKD receiver losses or not?**

b) **Which is the range of tolerable channel losses (from transmitting lens aperture to input fiber interface of the QKD receiver) representing Eagle1 baseline? Note: not including QKD Receiver and protocol losses.**

c) **Which is the range of tolerable losses from the entrance pupil of the receiving telescope to the fiber input interface of the QKD receiver?**

d) **Which is the range of tolerable losses from the entrance pupil of the receiving telescope to the fiber interface of the classical/quantum splitting unit?**

e) **Have Interferometer locking and clock-recovery and synchronization strategies been tested up to XX dB of channel losses?**

f) **Which is the atmosferic transmittivity at 1550 nm at Zenith you are considering in your baseline (e.g., 50%, 70%, 85%)?**

Answers:

a) 60 dB is a generic figure to give an order of magnitude of the losses that can be present in a space-to-ground channel.

b) Optical link budgets for EAGLE-1 are not publicly available at this stage.

c/d) Losses internal to the OGS will not be specified, as they are a design choice that must come from the OGS designer. The Optical ICD [RD01] contains the irradiance that will be available at the OGS aperture for the classical channel, while [RD02] contains the acceptable losses for the quantum channel.

e) End-to-end testing of the full QKD protocol is indeed part of the EAGLE-1 developments. The details of the test cannot be made publicly available at this stage.

f) This specific value is part of the overall link budget. As such, it is only one of the many contributors to the overall losses that are in the channel. The main models and atmospheric conditions considered in EAGLE-1 can be found in [RD01].

49. How many passages are necessary (on average) to accumulate a detection per basis key block of size 16.5 x 10^5 accordingly to your baseline?

The exact number depends on several factors, including the actual performance offered by the specific OGS.

50. Which software is in charge of throwing away the lateral non interfering peaks (the QKD Receiver SW of the QKD Processing platform)?

The QKD Receiver software is in charge of this.

51. Is the maximum optical loss of the receiver including or excluding SNSPD detection efficiency?

SNSPD detection efficiency is included in the maximum optical loss.

52. Referring to maximum background counts impinging on entrance fiber receiver:

a) **please clarify the definition of "in-band". Does this refer to standard "pass band" of DWDM components at -3dB, -1dB?**

b) **is this noise to be consider at the input fiber interface of the QKD receiver or before fiber coupling?**

c) **which are the assumptions underlying the reported numbers?**

d) **how it is possible to test this requirement in operative conditions?**

Answers:

a) This is referring to the entrance filter presented in slide 18 of “The Eagle 1 QKD Protocol”.

b) Please refer to question 47.

c) Please refer to question 47.

d) At this stage no details have been shared on testing activities needed to verify requirements.

53. If one has 800 Hz in-band how can be this noise reduce to 75 Hz?

Please refer to question 47.

54. When will documents "EAGLE1-00290-SYS-ICD-TST Optical Link ICD for the EU Make Option" and "EAGLE1-00451-V1.0-GQKD-DDF-FAU-x_QKD Ground System Design Definition" be available?

The first document is already available on SES website at the following link https://ses-techcom.com/download-category/eagle-1-documents/.

All the relevant information concerning the second document is contained in the publicly available information (slide decks on QKD protocol and synchronization).

55. Which are the interface of the RX/quantum fiber splitting unit?

All the details of the interface with the QKD receiver are described in the publicly available documentation. Interfaces that are internal to the OGS are in general out of scope of the published information.

56. Which are the polarization characteristics of the RX and quantum signals at that point? The downlink classical signal is said to be "unpolarized" in the free-space ICD document (EAGLE1-SYS-TE-ICD-0087)

Assuming that the question is referring to the air interface at the OGS, the QKD signal at the telescope aperture is circularly polarized (as described in [RD01]). After collection in the telescope, it is up to the OGS supplier to manage the polarization to optimize coupling into the PM fiber I/F with the QKD receiver.

57. With reference to the Polarization Extinction Ratio at the entrance of the QKD Receiver, please clarify between -20 and -25 dB.

The goal is to have a PER of -25 dB, -20 dB is the minimum acceptable value.

58. According to EAGLE1-SYS-TE-ICD-0087, the target Fried parameter is quite optimistic (10.3 cm @1550 at 20 deg elevation). Which are the real numbers SES is using?

The reported number is the one assumed for the baseline atmospheric condition (at night-time).

59. Referring to Optical ICD [RD01]: in the document, it is stated value assumes stare-stare. Please clarify PAT strategy. If stare-stare, please clarify CoU according to knowledge of satellite position

Refer to Table 4 of the document for the required values. Spiraling is also not excluded, if needed to fully illuminate the CoU.

60. The classical optical channel is following the SDA standard RD 2 , which was published beginning 2022 (Space Development Agency, Optical Intersatellite Link (OISL) Standard, version 2.1.2, SDA). Please confirm.

It is confirmed. The standard is then customized when needed, as presented in the Optical ICD [RD01].

61. Details on FOV, divergence, etc are missing from public documentation. Ask for more details, CoU, stare approach, etc. In the downlink tab, scanning is mentioned. Is this open?

Table 4 reports a high level description of the PAT strategy to ensure compatibility with the EAGLE-1 LCT. All the details concerning the OGS (such as the beacon divergence) should be proposed by the OGS supplier to ensure successful acquisition within the needed time and for the initial TUC specified in the table. Spiraling is also not excluded, if needed to fully illuminate the CoU.

[END OF DOCUMENT]