|  |  |  |
| --- | --- | --- |
|  | INTERNATIONAL TELECOMMUNICATION UNION**TELECOMMUNICATIONSTANDARDIZATION SECTOR**STUDY PERIOD 2022-2024 | FG-AI4H-S-046 |
| **ITU-T Focus Group on AI for Health** |
| **Original: English** |
| **WG(s):** | Plenary | Geneva, 3-5 July 2023 |
| **DOCUMENT** |
| **Source:** | Editor |
| **Title:** | DEL00 Update: Overview of the FG-AI4H deliverables |
| **Contact:** | Shan XuChina Academy of Information and Communication Technology(CAICT)China | Email: xushan@caict.ac.cn |
| **Contact:** | Ziyan GuanChina Academy of Information and Communication Technology(CAICT)China | Email: guanziyan@caict.ac.cn |

|  |  |
| --- | --- |
| **Abstract:** | This deliverable provides an overview of the planned deliverables for the ITU-T Focus Group on AI for health (FG-AI4H). This version contains the update for FG-AI4H meeting S, Geneva, 3-5 July 2023. A clean version is uploaded in the deliverables page of the Collaboration site as DEL00. This version is based on the update on FG-AI4H meeting Helsinki, 20-22 September 2022.  |

|  |  |
| --- | --- |
|  | **International Telecommunication Union** |
|  |  |
| **ITU-T** | **FG-AI4H Deliverable** |
| TELECOMMUNICATIONSTANDARDIZATION SECTOROF ITU | Draft 2022-09-19 |
|  |  |
|  | DEL00Overview of the FG-AI4H deliverables |
|  |  |

**Call for participation**

If you are interested in contributing to DEL.00 " *Overview of the FG-AI4H deliverables* " you are encouraged to contact Shan XU (xushan@caict.ac.cn) and the FG-AI4H secretariat (tsbfgai4h@itu.int). We would appreciate if you can briefly introduce yourself and your relevant expertise.

Change Log

This document contains Version 5 of the Deliverable DEL00 on "*Overview of the FG-AI4H deliverables*". This version is based on the update on FG-AI4H meeting P, Helsinki, 20-22 September 2022. Previous versions include:

* Version 5 (DEL 00, E-meeting “P”, 20-22 September 2022)
* Version 4 (DEL 00, E-meeting “M”, 28 – 30 September 2021)
* Version 3 (DEL 00, E-meeting "L", 19–21 May 2021)
* Version 2 (DEL 00, E-meeting "K", 27–29 January 2021)
* Version 1 (DEL 00, E-meeting "J", 29 September–02 October 2020)
* Version 0 with an initial outline (DEL 00, E-meeting "I", 7–8 May 2020)

|  |  |  |
| --- | --- | --- |
| **Editor:** | Shan XuChina Academy of Information and Communication Technology(CAICT)China | Email: xushan@caict.ac.cn |

**CONTENTS**

|  Page |
| --- |
| [1 Scope 3](#_Toc114506902)[2 References 3](#_Toc114506903)[3 Terms and definitions 5](#_Toc114506904)[4 Abbreviations 5](#_Toc114506905)[5 Introduction 6](#_Toc114506907)[6 Deliverables type 6](#_Toc114506909)[7 Deliverable structure 6](#_Toc114506910)[8 Deliverables status 7](#_Toc114506911) [Generalized 10](#_Toc114506912)[9 specifications summary 10](#_Toc114506913)[10 Topic groups summary 14](#_Toc114506914) |

**List of Tables**

|  Page |
| --- |
| [Table 1 – Updated list of deliverables (same as O-200) 7](#_Toc114506915)[Table 2 – Summary of generalized documents (DEL 1-9) 11](#_Toc114506916)[Table 3 – Summary of Topic Groups (DEL 10.1-10.24) 14](#_Toc114506917) |

**List of Figures**

|  Page |
| --- |
| [Figure 1 – FG-A4H Deliverables structure 7](#_Toc83652731) |

ITU-T FG-AI4H Deliverable DEL00

Overview of the FG-AI4H deliverables

Summary

This document provides the overview of the planned deliverables for the ITU-T Focus Group on AI for health (FG-AI4H) to provide a standardization framework on artificial intelligence for health with a combination of horizontal and vertical perspective. The horizontal perspective reviews the DEL 01-09 including the generalized considerations on ethics, regulatory, requirement, data processing, model training, model evaluation, adoption and scale-up, etc. The vertical perspective summarizes use cases in specific domain with corresponding artificial intelligence/ machine learning tasks, for example 23 topic description documents (DEL 10.1-DEL 10.23 as of 2022-06-02) of topic groups in the FG-AI4H.

Keywords

Artificial intelligence, Deliverables, Health, Overview, Structure

# Scope

This deliverable provides an overview of the planned deliverables for the ITU-T Focus Group on AI for health (FG-AI4H) to provide a standardization framework on artificial intelligence for health. The reviewed deliverables including 9 deliverables (DEL 1-9) focus on the generalized considerations on ethics, regulatory, requirement, data processing, model training, model evaluation, adoption and scale-up, etc., and 23 topic description documents (DEL 10.1-10.23 as of 2022-06-02) within specific health domains with corresponding AI/ ML benchmarking tasks.

# References

[ISO/IEC 2382:2015] ISO/IEC 2382:2015, Information technology — Vocabulary

[IEC 62304] IEC 62304:2006 + A1:2015, "Medical device software – Software life cycle processes"

[DEL00\_1] Common unified terms in artificial intelligence for health

[DEL00S] List of FG-AI4H deliverables (as of 2022-06-02)

[DEL01] Ethics and governance of artificial intelligence for health

[DEL 02] Overview of Regulatory Considerations on Artificial Intelligence for Health

[DEL 02\_1] Mapping of IMDRF essential principles to AI for health software

[DEL 02\_2] Good practices for health applications of machine learning: Considerations for manufacturers and regulators

[DEL03] AI4H requirement specifications

[DEL 04] AI software life cycle specification

[DEL 05] Data specification

[DEL 05\_1] Data requirements

[DEL 05\_2] Data acquisition

[DEL 05\_3] Data annotation specification

[DEL 05\_4] Training and test data specification

[DEL 05\_5] Data handling

[DEL 05\_6] Data sharing practices

[DEL 06] AI training best practices specification

[DEL 07] AI for health evaluation considerations

[DEL 07\_1] AI4H evaluation process description

[DEL 07\_2] AI technical test specification

[DEL 07\_3] ML4H trial audits–Iteration 2.0 Playbook (Version 3.0)

[DEL 07\_4] Clinical evaluation of AI for health

[DEL 07\_5] Assessment platform

[DEL 09] AI4H applications and platforms

[DEL 09\_1] Mobile Applications

[DEL 09\_2] Cloud-based AI applications

[DEL 10] AI4H use cases: Topic Description Documents

[DEL10\_01] FG-AI4H Deliverable DEL10\_01, C*ardiovascular disease management (TG-Cardio).*

[DEL10\_02] FG-AI4H Deliverable DEL10\_02, *Dermatology (TG-Derma).*

[DEL10\_03] FG-AI4H Deliverable DEL10\_03, *Diagnosis of bacterial infection and anti-microbial resistance (TG-AMR).*

[DEL10\_04] FG-AI4H Deliverable DEL10\_04, *Falls among the elderly (TG-Falls).*

[DEL10\_05] FG-AI4H Deliverable DEL10\_05, *Histopathology (TG-Histo).*

[DEL10\_06] FG-AI4H Deliverable DEL10\_06, *Malaria detection (TG-Malaria).*

[DEL10\_07] FG-AI4H Deliverable DEL10\_07, *Maternal and child health (TG-MCH).*

[DEL10\_08] FG-AI4H Deliverable DEL10\_08, *Neurological disorders (TG-Neuro).*

[DEL10\_09] FG-AI4H Deliverable DEL10\_09, *Ophthalmology (TG-Ophthalmo).*

[DEL10\_10] FG-AI4H Deliverable DEL10\_10, *Outbreak detection (TG-Outbreaks).*

[DEL10\_11] FG-AI4H Deliverable DEL10\_11, *Psychiatry (TG-Psy).*

[DEL10\_12] FG-AI4H Deliverable DEL10\_12, *Radiology (TG-Radiology).*

[DEL10\_13] FG-AI4H DEL10\_13, *Snakebite and snake identification (TG-Snake).*

[DEL10\_14] FG-AI4H Deliverable DEL10\_14, *Symptom assessment (TG-Symptom).*

[DEL10\_15] FG-AI4H Deliverable DEL10\_15, *Tuberculosis (TG-Tuberculosis)*.

[DEL10\_16] FG-AI4H Deliverable DEL10\_16, *Volumetric chest computed tomography (TG-Diagnostic CT).*

[DEL10\_17] FG-AI4H Deliverable DEL10\_17, *Dental diagnostics and digital dentistry (TG-Dental).*

[DEL10\_18] FG-AI4H Deliverable DEL10\_18, *AI-based detection of falsified medicine (TG-FakeMed).*

[DEL10\_19] FG-AI4H Deliverable DEL10\_19, *Primary and secondary Diabetes risk prediction (TG-Diabetes).*

[DEL10\_20] FG-AI4H Deliverable DEL10\_20, *AI for endoscopy (TG-Endoscopy).*

[DEL10\_21] FG-AI4H Deliverable DEL10\_21, *AI for Musculoskeletal medicine* *(TG-MSK).*

[DEL10\_22] FG-AI4H Deliverable DEL10\_22, *AI for human reproduction and fertility (TG-Fertility)*.

[DEL10\_23] FG-AI4H Deliverable DEL10\_23, *AI in sanitation for public health (TG-Sanitation)*.

[DEL10\_24] FG-AI4H Deliverable DEL10\_24, *AI for point-of-care diagnostics (TG-POC).*

NOTE: Literature references are listed in the bibliography.

# Terms and definitions

This document uses the following terms defined elsewhere:

**3.1 Algorithm [IMDRF/SaMD-N41]:** a finite set of instructions (or rules) that defines a sequence of operations for solving a particular computational problem for all problem instances for a problem set.

**3.2 Application [ITU-T H.764]:** A functional implementation realized as software running in one or spread over several interplaying hardware entities.

**3.3 Artificial intelligence [ISO/IEC 2382:2015]:** Branch of computer science devoted to developing data processing systems that perform functions normally associated with human intelligence, such as reasoning, learning, and self-improvement.

**3.4** **Bias [WHO AI-EG]:** A threat to inclusiveness and equity that represents a departure, often arbitrary, from equal treatment.

**3.5 Machine learning** [ISO/IEC 2382:2015]: Automatic learning, process by which a functional unit improves its performance by acquiring new knowledge or skills, or by reorganizing existing knowledge or skills.

# Abbreviations

|  |  |
| --- | --- |
| AHG | Ad hoc group |
| AI | Artificial Intelligence |
| DEL | Deliverable |
| FG | Focus Group |
| FG-AI4H | Focus Group on artificial intelligence for health |
| ITU | International Telecommunication Union  |
| ML | Machine Learning |
| TDD | Topic description document |
| TG | Topic groups |
| WG | Working group |
| WHO | World Health Organization |

# Introduction

The ITU/WHO Focus Group on artificial intelligence for health (FG-AI4H) was established by ITU-T Study Group 16 at its meeting in Ljubljana, Slovenia, 9-20 July 2018.  This group is committed to establish a standardized assessment framework for the evaluation of AI-based methods for health, diagnosis, triage or treatment decisions. A list of deliverables for the FG-AI4H was planned including 9 deliverables (DEL 1-9) focus on the generalized considerations on ethics, regulatory, requirement, data processing, model training, model evaluation, adoption and scale-up, etc., and 23 topic groups (DEL 10.1-10.23 as of 2022-06-02) within specific health domains with corresponding artificial intelligence (AI)/machine learning (ML) benchmarking tasks. With the increase and development of the deliverables, a compiled overview is to be built to give a quick review of all deliverables, therefore to facilitate collaboration and management of FG activities. It can also be used as a quick guild for new participants to understand FG-AI4H activities.

# Deliverables type

According to utilization scenario, the planned deliverables can be divided into two types:

* Generalized specifications (DEL 1-9): focus on the generalized specifications including ethics, regulatory, requirement, data, training, evaluation, application, etc. Each part is interconnected to form a life cycle process of AI-based methods for health.
* Topic description documents (DEL 10.1-10.24): focus on the use cases in specific health domains with corresponding AI/ML tasks. Each case can be regarded as an example of a whole process recommended by generalized specifications (DEL 1-9), and profiled in a specific application scenario.

# Deliverable structure

Figure 1 gives an overall structure of all deliverables from DEL 1-9 and DEL 10.1-10.24. The arrows between DEL 1-9 indicate sequential considerations from the perspective of AI implementation, which includes demand finding, solution (data preparation, model development and evaluation aspects), and finally scale-up and adoption to population. Topic groups (TGs) shown at the bottom considers the specific health domains with corresponding AI/ML tasks in the recommended process of the above generalized specifications. They provides the practical verification on specific health scenarios involved with a number of AI for health tasks and data modalities.



Figure 1 – FG-A4H Deliverables structure

# Deliverables status

Table 1 was extracted from document FG-AI4H-O-200 with a link of each document for more details, it shows the current status of FG-AI4H deliverables and is continuously updated based on the output list from focus group meetings, management and feedback from editors. Colour codes indicate deliverable drafting status (as of the issuance of this document) as "*active*" (green) and "*unclear whether active*" (blue).

Table 1 – Updated list of deliverables (same as O-200)

| No. | Deliverable | Updated initial draft editor | Availability\* |
| --- | --- | --- | --- |
| 0 | Overview of the FG-AI4H deliverables | Shan Xu (CAICT, China) | [M-044](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-M-044.docx)([O-050](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-N-050.pptx)) |
| 0.1 | Common unified terms in artificial intelligence for health | Markus Wenzel (Fraunhofer HHI, Germany) | [O-040](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-N-040.docx) |
| 1 | AI4H ethics considerations | Andreas Reis (WHO) | [O-201](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-N-201.docx) |
| 2 | Overview of regulatory considerations on artificial intelligence for health | Shada Alsalamah (WHO) | [O-049](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-N-049.docx) |
| 2.1 | Mapping of IMDRF essential principles to AI for health software | Luis Oala (Fraunhofer HHI, Germany), Pradeep Balachandran (Technical Consultant eHealth, India), Pat Baird (Philips, USA), Thomas Wiegand (Fraunhofer HHI, Germany) | [G-038](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-G-038.docx), [G-038-A01](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-G-038-A01.xlsx) |
| 2.2 | Good practices for health applications of machine learning: Considerations for manufacturers and regulators | Pradeep Balachandran (India) and Christian Johner (Johner Institut, Germany) | [O-031](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-N-031.docx) |
| 3 | AI4H requirement specifications | Pradeep Balachandran (India) | [O-032](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-N-032.docx) |
| 4 | AI software life cycle specification | Pat Baird (Philips, USA) | [J-033](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-J-033.docx)([L-046](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-L-046.pptx)) |
| 5 | Data specification | Marc Lecoultre (MLlab.AI, Switzerland) | [G-205](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-G-205.docx) |
| 5.1 | Data requirements | [Marc Lecoultre (MLlab.AI, Switzerland)]\*\* | [I-044](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-I-044.docx) |
| 5.2 | Data acquisition  | Rajaraman (Giri) Subramanian (Calligo Tech, India), Vishnu Ram (India) | [G-205-A02](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-G-205-A02.docx) |
| 5.3 | Data annotation specification | Shan Xu (CAICT, China), Harpreet Singh (ICMR, India), Sebastian Bosse (Fraunhofer HHI, Germany) | [M-045](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-M-045.docx) |
| 5.4 | Training and test data specification  | Luis Oala (Fraunhofer HHI, Germany), Pradeep Balachandran (India) | [I-034](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-I-034.docx)([L-045](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-L-045.pptx)) |
| 5.5 | Data handling  | Marc Lecoultre (MLlab.AI, Switzerland) | [I-045](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-I-045.docx) |
| 5.6 | Data sharing practices | Ferath Kherif (CHUV, Switzerland), Banusri Velpandian (ICMR, India), WHO Data Team | [L-044](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-L-044.pptx) |
| 6 | AI training best practices specification | Xin Ming Sim and Stefan Winkler (AI Singapore) | [K-037](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-K-037.docx) |
| 7 | AI for health evaluation considerations | Markus Wenzel (Fraunhofer HHI, Germany) | [O-042](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-N-042.docx) |
| 7.1 | AI4H evaluation process description | Vacant | [G-207-A01](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-G-207-A01.docx) |
| 7.2 | AI technical test specification | Auss Abbood (Robert Koch Institute, Germany) | [I-027](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-I-027.docx)([L-051](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-L-051.pptx)) |
| 7.3 | Data and artificial intelligence assessment methods (DAISAM) reference | Luis Oala (Fraunhofer HHI, Germany) | [O-033](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-N-033.docx)([L-052](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-L-052.pptx)) |
| 7.4 | Clinical evaluation of AI for health | Naomi Lee (Lancet, UK), Eva Weicken (Fraunhofer HHI, Germany), Shubhanan Upadhyay (ADA Health, Germany) | [O-048](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-N-048.docx) |
| 8 | AI4H scale-up and adoption | Sameer Pujari (WHO), Yu ZHAO and Javier Elkin [Previously: Robyn Whittaker (New Zealand)] | –([K-052](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-K-052.pptx)) |
| 9 | AI4H applications and platforms | Manjeet Chalga (ICMR, India) | [L-050](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-L-050.docx) |
| 9.1 | Mobile applications | Khondaker Mamun (UIU, Bangladesh), Manjeet Chalga (ICMR, India) | [N-043](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-N-043.docx) |
| 9.2 | Cloud-based AI applications | Khondaker Mamun (UIU, Bangladesh) | [I-049](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-I-049.docx) |
| 10 | AI4H use cases: Topic description documents | Eva Weicken (Fraunhofer HHI, Germany) | [O-041](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-O-041.docx) |
| 10.1 | Cardiovascular disease management (TG-Cardio) | Benjamin Muthambi (Watif Health, South Africa) | [O-006-A01](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-O-006-A01.docx) |
| 10.2 | Dermatology (TG-Derma) | Weihong Huang (Xiangya Hospital Central South University, China)NOTE – Maria Vasconcelos (Fraunhofer, Portugal) resigned from the role. | [O-007-A01](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-O-007-A01.docx) |
| 10.3 | Diagnosis of bacterial infection and anti-microbial resistance (TG-Bacteria) | Nada Malou (MSF, France) | [O-008-A01](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-O-008-A01.docx) |
| 10.4 | Falls among the elderly (TG-Falls) | Pierpaolo Palumbo (University of Bologna, Italy); Inês Sousa (Fraunhofer Portugal) | [O-012-A01](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-O-012-A01.docx) |
| 10.5 | Histopathology (TG-Histo) | Frederick Klauschen (LMU Munich & Charité Berlin, Germany) | [O-013-A01](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-O-013-A01.docx) |
| 10.6 | Malaria detection (TG-Malaria) | Rose Nakasi (Makerere University, Uganda) | [O-014-A01](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-O-014-A01.docx) |
| 10.7 | Maternal and child health (TG-MCH) | Raghu Dharmaraju (Wadhwani AI, India) and Alexandre Chiavegatto Filho (University of São Paulo, Brazil) | [O-015-A01](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-O-015-A01.docx) |
| 10.8 | Neurological disorders (TG-Neuro) | Marc Lecoultre (MLlab.AI, Switzerland) and Ferath Kherif (CHUV, Switzerland) | [O-016-A01](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-O-016-A01.docx) |
| 10.9 | Ophthalmology (TG-Ophthalmo) | Arun Shroff (MedIndia) | [O-017-A01](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-O-017-A01.docx) |
| 10.10 | Outbreak detection (TG-Outbreaks) | Auss Abbood and Alexander Ullrich (Robert Koch Institute, Germany); Khahlil Louisy and Alexander Radunsky (Institute for Technology & Global Health, ITGH, US) | [O-018-A01](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-O-018-A01.docx) & [O-028-A01](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-O-028-A01.docx) |
| 10.11 | Psychiatry (TG-Psy) | Nicolas Langer (ETH Zurich, Switzerland) | [O-019-A01](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-O-019-A01.docx) |
| 10.12 | AI for radiology (TG-Radiology) | Darlington Ahiale Akogo (minoHealth AI Labs, Ghana) | [O-023-A01](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-O-023-A01.docx) |
| 10.13 | Snakebite and snake identification (TG-Snake) | Rafael Ruiz de Castaneda (UniGE, Switzerland) | [O-020-A01](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-O-020-A01.docx) |
| 10.14 | Symptom assessment (TG-Symptom) | Henry Hoffmann (Ada Health, Germany) and Martin Cansdale (Healthily, UK) | [O-021-A01](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-O-021-A01.docx) |
| 10.15 | Tuberculosis (TG-TB) | Manjula Singh (ICMR, India) | [O-022-A01](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-O-022-A01.docx) |
| 10.16 | Volumetric chest CT (TG-DiagnosticCT) | Kuan Chen (Infervision, China) | [O-009-A01](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-O-009-A01.docx) |
| 10.17 | Dental diagnostics and digital dentistry (TG-Dental) | Falk Schwendicke and Joachim Krois (Charité Berlin, Germany); Tarry Singh (deepkapha.ai, Netherlands) | [O-010-A01](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-O-010-A01.docx) |
| 10.18 | Falsified Medicine (TG-FakeMed) | Franck Verzefé (TrueSpec-Africa, DRC) | [O-011-A01](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-O-011-A01.docx) |
| 10.19 | Primary and secondary diabetes prediction (TG-Diabetes) | Andrés Valdivieso (Anastasia.ai, Chile) | [O-024-A01](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-O-024-A01.docx) |
| 10.20 | AI for endoscopy (TG-Endoscopy) | Jianrong Wu (Tencent Healthcare, China) | [O-025-A01](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-O-025-A01.docx) |
| 10.21 | AI for musculoskeletal medicine (TG-MSK) | Peter Grinbergs (EQL, UK), Yura Perov (UK) | [O-026-A01](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-O-026-A01.docx) |
| 10.22 | AI for human reproduction and fertility (TG-Fertility) | Susanna Brandi, Eleonora Lippolis, (Merck KGaA, Darmstadt, Germany) | [O-027-A01](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-O-027-A01.docx) |
| 10.23 | AI for point-of care diagnostics (TG-POC) | Nina Linder, University of Helsinki, Finland | [O-029-A01](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-O-029-A01.docx) |

NOTES

\* Some links provided are to slide sets; these slide sets are not meant to be the deliverable documents, but rather a status update concerning progress of the respective deliverable. Documents in parenthesis are status updates, not a deliverable text.

\*\* Acting editor

Possible future Deliverables:

| No. | Deliverable | Updated initial draft editor | Reference |
| --- | --- | --- | --- |
| – | Open Code Initiative reference software implementation | Marc Lecoultre (MLlab.AI, Switzerland) | [K-043](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-K-043.docx) |
| – | Risk management in AI for health | Pat Baird (Philips, USA) | [K-034](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-K-034.pptx)  |

Initial public version already available:

| No. | Deliverable | Editor(s) | Reference |
| --- | --- | --- | --- |
| [AHG-DT4HE Output 1](https://www.itu.int/en/ITU-T/focusgroups/ai4h/Documents/FGAI4H-DT4HE-O-001.pdf) | Guidance on digital technologies for COVID health emergency | Shan Xu (CAICT, China), Ana Riviere-Cinnamond (PAHO)  | [K-042](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-K-042.docx) |
| [TG-Dental Output 1](https://www.itu.int/en/ITU-T/focusgroups/ai4h/Documents/FGAI4H-TG-Dental-O-001.pdf) | Artificial intelligence in dental research: A checklist for authors and reviewers | Falk Schwendicke, Joachim Krois (Charité Berlin, Germany) | [M-004](https://extranet.itu.int/sites/itu-t/focusgroups/ai4h/docs/FGAI4H-M-004.docx) |

# Generalized specifications summary

A summary of the generalized considerations is compiled here is to provide a general standardization framework on ethics, regulatory, requirement, data processing, model training, model evaluation, adoption and scale-up, etc. on AI for health. These key message also provides suggestion for each DEL editor to avoid possible conflicts or overlap in documents scope, therefore facilitate collaboration and adaption between different use cases.

Table 2 – Summary of generalized documents (DEL 1-9)

| **Deliverable** | **Scope** | **Last update** |
| --- | --- | --- |
| **1- AI4H ethics considerations** | The rapidly developing field of AI raises a number of ethical, legal and social concerns, e.g. regarding equitable access, privacy, appropriate uses and users, liability and bias and inclusiveness. These issues are trans-national in nature, as capturing, sharing and using data generated and/or used by these technologies goes beyond national boundaries. Many questions remain unanswered concerning the ethical development and use of these technologies, including how low- and middle-income countries will benefit from AI developments. This document is to develop a harmonised ethics guidance for the design and implementation of AI in global health.  | 05/31/2022 |
| **2- Overview of regulatory considerations on artificial intelligence for health** | This document is aimed as a general, high-level, and nonexclusive overview of key regulatory considerations’ topic areas delivered by the WG-RC on AI for health. It highlights some of the key regulatory principles and concepts, such as risk/benefit assessments and considerations for the evaluation and monitoring of the performance of AI solutions.  | 05/31/2022 |
| 2.1 | Mapping of IMDRF essential principles to AI for health software | This document provides a number of new aspects that have not been considered when developing the regulatory framework for software as a medical device (SaMD) as described by the IMDRF Essential Principles (EPs) in “Essential Principles of Safety and Performance of Medical Devices and IVD Medical Devices”, IMDRF Good Regulatory Review Practices Group, IMDRF GRRP WG/N47 FINAL, 31 October 2018. This document provides a suggested mapping of the EPs to related aspects of AI4H software. Its purpose is to cover all aspects considered in the regulation of SaMDs and whether and if yes, how they are applicable to AI4H. | 5/18/2020 |
| 2.2 | Good practices for health applications of machine learning: Considerations for manufacturers and regulators | This document recommends a set of good machine learning practice guidelines to the manufacturers and regulators of data driven Artificial Intelligence based healthcare solutions on conducting comprehensive requirements analysis and streamlining conformity assessment procedures for continual product improvement in an iterative and adaptive manner. This set of good machine learning practice guidelines gives prime priority to the factor of patient safety and focuses on a streamlined process for risk minimization and quality assurance for AI/ML based health solutions and tries to establish a system of transparency and accountability of all the processes involved in AI/ML based health solutions.  | 05/31/2022 |
| **3- AI4H requirements specification** | This document is to define the System Requirement Specifications (SyRS) that explains the informational, functional, behavioural and operational aspects a generic AI for health (AI4H) system. SyRS serves as the basis and helps to create system design, system verification and validation plans and procedures. System requirements analysis methodology follows a collaborative team-oriented approach, involving all the working groups and topic groups of AI4GH FG, to help the project team identify, control and track various requirements and changes to those requirements during the AI4H system development lifecycle. | 05/31/2022 |
| **4-AI software life cycle specification** | This deliverable includes the following considerations: a) Identification of all standards and best practices that are relevant for the AI for health software life cycle. Similar to other software life cycle processes, the AI software life cycle process needs to be specified. b) Summary and critical review of the identified documents including a discussion of their limits/gaps and need for action. C) Identification of life cycle steps that are specific/characteristic for AI for health software, such as training and test procedures based on data that potentially need to be annotated. d) Specification of the AI for health software life cycle and definition of best practices for the different life cycle steps in one document (under consideration of a, b, and c). Overview and examples of best practices | 9/28/2020 |
| **5-Data specification** | This document combines a set of six separate deliverables as umbrella, which address six important aspects related to data specification when used for artificial intelligence (AI) and machine learning (ML) models/methods for health purposes. Each editor will propose an initial outline (=Table of Contents), define the objectives of the future deliverable, and collect a bibliography of existing literature and material relevant for the development of the respective document. A short call for participation, the expertise profile of potential contributors, a time plan, and a brief characterisation of the target audience serve as preface. | 6/17/2020 |
| 5.1 | Data requirements | This document lists acceptance criteria for data submitted to the FG-AI4H and states the governing principles and rules. These principles are crucial because the core of the benchmarking framework for AI for health methods will be an undisclosed test data set – per use case of each topic area to be defined – that will not be made accessible to the AI developers.  | 5/19/2020 |
| 5.2 | Data acquisition | This document presents a framework for public healthcare data acquisition and management model based on standard protocol for its easy adoption by any country or international health organizations. This paper assumes basic digitization of electronic health record (EHR) at basic health facilities. There is a gap in developing an integrated and comprehensive framework that addresses the use of EHR in a standardized way for public health, privacy issue by anonymizing patient specific information, fusing multiple records with slight changes in the same information, augmenting a broad spectrum of contextual data, and so on.  | 5/19/2020 |
| 5.3 | Data annotation specification | This document is committed to give a general guideline of data annotation specification, including definition, background and goals, framework, standard operating procedure, scenario classifications and corresponding criteria, as well as recommended metadata, etc. A questionnaire is attached to seek input and collaboration with topic groups in FG-AI4H regarding data annotation. | 1/27/2021 |
| 5.4 | Training and test data specification | This document is intended to guide the target audience with a systematic way of preparing technical requirements specification for datasets used in training and testing of machine ML models This document explains the best practices of data quality assurance aimed at minimizing the data error risks during the training and test data preparation phase of machine learning process lifecycle. The training and test data requirement specifications follow the data integrity, data security and data safety norms of the AI data governance lifecycle process. | 5/20/2020 |
| 5.5 | Data handling | This document outlines how data will be handled, once they are accepted. Health data are one of the most valuable and sensitive types of data. Handling this kind of data is often associated with a strict and factual framework defined by data protection laws. There are two major issues that the data handling policy should address: (a) compliance with regulations dealing with the use of personal health data; and (b) non-disclosure of the undisclosed test data held by FG-AI4H for the purpose of model evaluation. | 4/1/2020 |
| 5.6 | Data sharing practices | This document aims to provide an overview of the existing best practices for data sharing of health-related data, including the requirement to enable secure data sharing and issues related to data governance. The documents described established solutions and novel approaches based on distributed and federated environments.  | 5/19/2021 |
| **6-AI training best practices specification** | This document aims to provide best practices for training and documentation so as to facilitate maximum performance and transparency. This document provides a review of the different aspects of AI model training pipeline. The first part discusses the best practices for data pre-processing aspects, while the second part discusses the best practices for AI model training aspects. | 1/25/2021 |
| **7-AI for health evaluation considerations** | This introduction with considerations on the evaluation of AI for health sets the scene for the five related documents DEL07.1-5. In this document, an overview of the deliverables DEL7.1-5 is given, preliminary considerations on the evaluation process are being made, characteristics of health AI validation and evaluation that are novel are identified, and the concept of standardized model benchmarking is introduced. Moreover, requirements for a benchmarking platform are considered in detail and best practices for the health AI model assessment are collected from selected sources.  | 05/31/2022 |
| 7.1 | AI4H evaluation process description | The AI4H evaluation process description serves as overview of the state of the art of AI evaluation principles and methods and a forward-looking initiator for the evaluation process of AI4H. This process description includes a review of existing evaluation principles and methods, evaluation need and solutions specific for AI4H. It will also look into ethics and risks aspects of AI4H evaluation. Furthermore, based on the fundamentals of AI, the description will gain insights on the direction of how the current evaluation methods evolve towards the concept of REAL AI. | 5/20/2020 |
| 7.2 | AI technical test specification | This document specifies how an AI can and should be tested in silico. Among other aspects, best practices for test procedures known from (but not exclusively) AI challenges will be reviewed in this document. Important testing paradigms that are not exclusively related to AI applications should be mentioned too. | 5/20/2020 |
| 7.3 | Data and artificial intelligence assessment methods (DAISAM) reference | This document provides a summary of how to understand and identify algorithmic bias at different stages of the AI-based product that may have critical implications when the algorithm is applied in a real-world clinical setting. The aim is to train the most accurate model for each group without harming any minority group of patients. Furthermore, methods to mitigate bias according to the problem at hand are provided. These guidelines aim to provide a framework for technologists that build health related AI based products to investigate the presence of algorithmic bias. | 05/31/2022 |
| 7.4 | Clinical evaluation of AI for health | This document is to outline the current best practices, the principles and outstanding issues for further considerations related to clinical evaluation of AI health technologies. It serves as the output document of the WHO/ITU Focus Group on AI for Health (FG-AI4H) Working group on Clinical Evaluation of AI for Health (WG-CE).  | 05/31/2022 |
| **8-AI4H scale-up and adoption** |  | —— |
| **9-AI4H applications and platforms** | This document contains a discussion on development of AI tool for Health using Mobile Applications & Cloud-based AI applications. This document describes type of mobile applications and the development of App based system for disease surveillance in the health sector.  | 5/20/2020 |
| 9.1 | Mobile applications | This document contains a draft set of rules for development of AI tool for Health using Mobile Applications, their testing and benchmarking. It is to prepare the rules for development of AI tool for Health using Mobile Applications, and discuss the regulatory/ethical rules for Mobile Apps with AI for Healthcare. | 5/21/2021 |
| 9.2 | Cloud-based AI applications | This document contains a draft set of rules for development of Cloud-based AI applications, their testing and benchmarking. It is to discuss on technology, security and legal issues related to cloud-based AI tools, and to provide a forum for open communication among various stakeholders. | 5/21/2020 |

# Topic groups summary

To provide a quick overview of the specific health domains with corresponding AI/ML tasks considered in FG-AI4H, a summary table of all Topic Description Documents (TDD) is given below. Key messages includes health domain, task classification, gold standard, input data type, testing/training dataset, data annotation, algorithm, evaluation, etc. These information listed below were obtained from 7 responses of a questionnaire to all TG drivers (<https://forms.gle/3fYrm3SZSrNQu3eeA>), the remaining blank will be filled through a comprehensive review of all TDDs.

Table 3 – Summary of Topic Groups (DEL 10.1-10.24)

| Topic Groups (Examples) | Domain (Cardiovascular/ Dermatology/ Histopathology/‌etc.) | Task (Classification/ detection/ segmentation/ prediction/‌etc.) | Gold Standard (state-of-the-art task intervention method) | Input data type (Text/ Image/ video/ audio/ numerical/‌etc.) | Testing/ Training dataset (Public dataset/ Collected by myself/‌etc.) | Data annotation (Procedure/ annotator number/ tool/‌etc.) | Algorithm (specific model used in this TG) | Evaluation (Metrics used in this TG) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| TG-Bacteria | Diagnoses of bacterial infection and anti-microbialresistance | Classification | clinical microbiologists with 4 to 5 years of specialization  | 2D Image | Self-built | Manual annotation | Models were trained using Tensorflow in Python via Google Colab; Artificial Neural Networks/ANNs | Accuracy |
| TG-Cardio | cardiovascular disease | prediction | clinical CVD risk scoring tools/calculators (WHO, 2019) | Quantitative & qualitative data (structured) | De-identified retrospective secondary data from healthcare/EMR & research data repositories | Structured data are used, thus simple R programming is used to recode structured data to required standardized labels. | Support Vector Machines/SVM; Random Forest/RF; & Artificial Neural Networks/ANNs | Accuracy of each risk prediction; Kappa statistic |
| TG-Dental | Dental diagnostics and digital dentistry | Classification/ detection/ segmentation/ prediction | Histology, Cross-image validation, human annotations | 2D Image, 3D Image, Video, Text | Self-built | Custom made tool | ML/DP models; ML approach based on a multicenter datasetof panoramic radiographs (OPGs) and electronic medical records (EMR) |  Accuracy, Sensitivity/recall, Specificity, Positive predictive value/precision, Negative predictive value, Area under the curve, F1-score/Dice score, Intersection over Union, AFROC, among others |
| TG-Derma | Dermatology | Classification | Not mentioned | 2D Image  | Public dataset（EDRA,ISIC, Dermofit, AICOS） and private data | Manual annotation | Not mentioned | Sensitivity;Specificity; F1-score |
| TG-Diabetes | Primary and secondary diabetes prediction |  Classification/ detection/ prediction/ segmentation | Biological markers | 2D Image |  Publicly dataset (EyePACS), MESSIDOR dataset, The DIARETDB dataset, Diabetic retinopathy datasets from Kaggle, undisclosed data | Manual annotation |  Not mentioned |  Accuracy; Cohen's Kappa and QuaDiabetic retinopathyatic Weighted Kappa |
| TG-DiagnosticCT | Volumetric chest computed tomography |  Classification/detection/segmentation | Cross annotation by doctors, Pathological report | 2D Image | Public dadset; Self-built | Cross annotation | slice-aware network (SANet) | Nodule-based sensitivity, false positive rate, free-response ROC, location ROC, AFORC,F-score, time spent reading the cases; varying sizes, varying densities, varying shapes; Nodule characterization, Subtle case performances |
| TG-Endoscopy | Endoscopy | Classification/ detection/ segmentation | Pathological report, Cross annotation by doctors  | 2D Image, Video | Public dataset， self-built | Cross annotation, Self-built annotation tool  | deep CNN based on SegNet architecture |  True positive (TP)True negative (TN), False-positive (FP), False-negative (FN), Recall (REC) or Sensitivity (SENS), Precision (PREC), Specificity (SPEC), Accuracy(ACC), Matthews correlation coefficient (MCC), Fl score (F1), DICE coefficient(DICE), Jaccard coefficient or Intersection over Union(IoU), Polyp detection rate (PDR), Adenoma detection rate(ADR), Detection Latency, Average precision(AP), mAP, Runtime |
| TG-FakeMed | AI-based detection of falsified medicine | Classification/ detection/ prediction | Not mentioned | 2D Image, Text | Self-built | Python/pip LabelIng | the Random Forest algorithm | relation to parameters stakeholders need for decision making, scores that providers use, the scope providers designed their solutions for, the state of the art in RCT, statistics, AI benchmarking etc., bias transparency |
| TG-Falls | Falls among the elderly | Prediction | Systematic reviews report, algorithm | table and additional text files | public dataset, Anonymised Microfile Dataset | Manual annotation | Supervised Learning | The AUC, The sensitivity and specificity at a cut-off maximising the Youden index, The Brier score |
| TG-Fertility | Human reproduction and fertility | Identification, diagnosis, and treatment decision support | Relies solely in human judgment based on currently identified biomarkers |  Demographics, genomics, behaviours and lifestyle, medical history, prior fertility treatments, fertility treatment protocols, cycle data, and gamete and embryo development | Not mentioned | Not mentioned | Not mentioned | Not mentioned |
| TG-Histo | Histopathology | Detection | Histopathology | 2D Image | Self-built | Web-based annotation tool | Patch-wise classification | The detection performance (accuracy, F1 score, area under the curve of the receiver operating characteristic etc.) and the quantification error (e.g., the root mean square error) |
| TG-Malaria | Malaria detection | Detection | Manual microscopy | 2D Image | Self-bult | Manual annotation | Image processing algorithm based on a pre-trained model of Faster Convolutional Neural Network (Faster R-CNN) and then integrated it with web-based technology; Mobile-Aware Deep Learning Algorithms | ROC accuracy, precision, recall, specificity F1 scores, specificity, sensitivity, mean Average Precision (mAP), average precision |
| TG-MCH | Maternal and child health | Prediction; warning  | AI applications | Numeric variable, coded variable | Public dataset  | Not mentioned | lightgbm (LGBM), xgboost (XGB), adaboost, catboost and random forest | AUC-ROC, precision, recall, accuracy, and F1-score |
| TG-MSK | Musculoskeletal medicine | Prevention, diagnosis, prognosis and treatment  | Prediction modelling | EQ-5D-3L (VAS), Oxford Hip and Knee Score (Q score) | Self-built | Manual annotation | Not mentioned | Classifier’s output value, Classifier certainty/uncertainty, Recall / sensitivity / true positive rate, Precision / positive predictive value |
| TG-Neuro | Neurological disorders | Classification/ detection/ prediction | Post-mortem pathology evaluation, and biological markers. | 2D Image, 4D Image, clinical scores, genetics and biomarkers (e.g. csf) | Public dataset, self-built. | Manual annotation | Machine learning algorithm | Test accuracy, Clinical sensitivity, Clinical specificity, Clinical precision |
| TG-Ophthalmo | Ophthalmology | Classification/ detection/ segmentation/ | Pathological report, Cross annotation by doctors | 2D Image, 3D Image, Text | Public dataset, self-built | Cross annotation, Self-built annotation tool | Neural networks and deep learning for image recognition and classification; Decision Tree | Sensitivity or Recall or True Positive Rate, Specificity or True negative rate, Precision or Positive Predictive Value, F1-Score, Accuracy, AUC (Area Under Receiver Operating Curve or ROC) |
| TG-Outbreaks | Outbreak detection | Detection, prediction | Incorporated syndromic surveillance systems and valuable external data sources  | Outbreak cases per week | Public dataset, and private data  | Manual annotation | CUSUM, regression models | Sensitivity, Specificity, Precision, Negative predictive value, F1, ROC/AUC, Matthews Correlation Coefficient, Scaled probability of detection (POD), the Scaled POD, the Scaled POD, the average time before detection, absolute delays in detection  |
| TG-POC | point-of care diagnostics | Diagnostic | Visual inspection with acetic acid (VIA), cytology-based screening tests, polymerase chain reaction (PCR) | 2D Image | Self-built (from TG-POC) | Seelf-comtrol | Image-based deep learning algorithm; an algorithm based on deep convolutional neural networks | Diagnostic accuracy (sensitivity, specificity, positive and negative predictive value), Cost-efficiency |
| TG-Psy | Psychiatry | Classification | Using classification schemes such as DSM-V and ICD-10 | 2D image (resting state EEG data) | Public dataset | Manual annotation | Deep learning, interpretable DNNs | Accuracy |
| TG-Radiology | Radiology | Detection | Using Deep Learning to detect diseases via medical images | 2D image or 3D image, DICOM or some other format | Public dataset | Not mentioned | Convolutional Neural Networks, Transfer Learning, DenseNet 121, Bayesian Optimization, Strong Augmentations,  | Classification Accuracy, Classification Error, Patient Level Accuracy & Image Level Accuracy, Pixel Accuracy, Exact Match Ratio (EMR), Example-Based Accuracy, Macro Averaged Accuracy, Micro Averaged Accuracy, Sensitivity, Specificity, Geometric mean (G-Mean), Precision, Recall, F-Measure, Fbeta-Measure, Matthews Correlation Coefficient (MCC), Macro Averaged Precision, Micro Averaged Precision, Macro Averaged Recall, Micro Averaged Recall, Negative Predictive Value (NPV), Receiver Operating Characteristic (ROC) Curve, Precision-Recall Curve, Average Precision (AP), Mean Average Precision (mAP), Logarithmic loss or Cross-entropy, Brier Score, Brier Skill Score, Intersection Over Union (IoU), Hamming Loss, α- Evaluation Score |
| TG-Sanitation | Sanitation for public health | Vacant  | Vacant  | Vacant  | Vacant  | Vacant  | Vacant  | Vacant  |
| TG-Snake | Snakebite and snake identification | Classification | Snake expert (herpetologist) identification | 2D Image | Public dataset, self-built. | Expert identification, crowdsourcing | AICrowd direct ingestion of algorithms & live leaderboard top algorithm available via API | F1 and logloss, scores that providers use, the scope providers designed their solutions for, the state of the art in RCT, statistics, AI benchmarking, bias transparency  |
| TG-Symptom | Symptom assessment | Classification | Average doctor opinion. | Text, semantically structured cases. | Self-built. | a new case-creation tool | Vacant  | Intended use of the device， Intended users， Risk classification， Point of Information and comparison to Standard of CareIntended/stated benefits to the user, clinical workflow and health system |
| TG-TB | Tuberculosis | Detection, identification, segmentation | Doctors-experts marking | 2D Image | Not mentioned | Manual annotation, Cross annotation  | Deep fully convolutional neural network (FCN) model | AUC, accuracy, sensitivity, specificity |

\* NOTE: Colour codes indicate TGs’ status reflected in FG-AI4H website, as “active groups" (green) and “starting groups" (blue) as of 2021-05-28.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_