STATEMENT OF WORK

1. Scope

The End-User) has a goal to develop neutron beam instruments to fully utilize its reactor and to advance the country's science and research base. This begins with the development of the tangential beam port NB-1 of their 2 MW TRIGA reactor, located within the Forest Maâmora, about 20 km northeast of Rabat.

1.1. This Statement of Work ("SoW") describes requirements for the design and engineering of an integrated system ('the System') that shall consist of a prompt gamma neutron activation analysis (hereinafter referred to as "PGAA") spectrometer and neutron imaging (including radiography and tomography and hereinafter referred to as "NRAD") facility located outside the NB-1 tangential neutron beam port. The System shall have the ability to switch easily between these two modalities (PGAA and NRAD).

1.2. The End-User has a basic conceptual design in need of engineering design assistance to become finalised. The scientific performance requirements are known, as are most of the physical components. The electrical systems such as translators, control electronics, and control software remain largely undefined. The Contractor shall work with the End-User to finalise the conceptual design and take the project to the detailed engineering design stage to a level of definition and with documentation complete enough to be used for a tender for procurement for the manufacture and installation of the System;

1.3. The following areas are within scope of this contract and are further defined hereinbelow. These areas include but are not necessarily limited to:

1.3.1. Design of mechanical systems not provided by the End User;
1.3.2. Definition of a motor control system and of a safety system;
1.3.3. Design of interfaces between the System, the reactor hall, utilities, bunker shielding and the primary shutter for the neutron beam;
1.3.4. Definition of the position and types of required utility services;
1.3.5. Opinions of Cost for construction and installation of the System;
1.3.6. Definition of an installation plan; and
1.3.7. Inputs to documentation for a safety case for the System.

1.4. The following areas are outside of the scope and are not the responsibility of the Contractor:

1.4.1. Design of the bunker shielding that surrounds the System and responsibility for the effectiveness of that shielding with respect to ionizing radiation;
1.4.2. Completion of the safety report or gaining approval for installation of the System by the End-User, the national nuclear regulatory agency (Agence Marocaine de Sûreté et de Sécurité Nucléaires et Radiologiques), or other authorities;
1.4.3. Programming of software to control scans for the System; and
1.4.4. Procurement, construction, and installation of the System.

2. Applicable Documents

The following documents shall be applicable for this Statement of Work to the extent specified hereinafter:

2.1. National Pressure Vessel Regulations : Réglementation des Appareils à Pression de Gaz au Maroc. http://www.mem.gov.ma/SiteAssets/AVG/DAHIR12Jan1955.pdf

2.2. IEC/EN 62061, “Safety of machinery: Functional safety of electrical, electronic and programmable electronic control systems”;

2.3. IAEA-TECDOC-348: Earthquake resistant design of nuclear facilities with limited radioactive inventory IAEA 1985, https://inis.iaea.org/collection/NCLCollectionStore/_Public/17/016/17016231.pdf?r=1&r=1

2.4. National regulations concerning seismic construction: Le Règlement de Construction Parasismique (RPS 200-Version 2011), http://www.sodibet.com/telechargement/RPS2011.pdf

2.5. Appendices A and B give an outline of the existing conceptual designs for PGAA and NRAD.

2.6. Appendices C to H give information about the building in which the System shall be installed, the fluxes, and components already owned by the End-User that shall be incorporated into the System by the Contractor.

In the event of conflict between the documents listed above and the content of this Statement of Work, the content of this Statement of Work shall take precedence to the extent of the conflict.

3. End-User Responsibilities

3.1. The End-User will in a timely manner:

3.1.1. ensure that all site-specific engineering requirements are clearly communicated to the Contractor in a timely manner;

3.1.2. define the information that is required from the Contractor to assist the End-User in producing a safety case for eventual installation of the System;

3.1.3. provide MCNP calculations performed along the beam path to define neutron and activation gamma fields, flux distributions, and beam divergence at specific points, if requested by the Contractor;

3.2. The End-User, at its cost, will design, engineer, and construct the biological shielding which will surround the System, which will be in the form of a bunker (“casemate”). The End-User will supply design information about this bunker to the Contractor and make adaptions if required to route utility services. Appendix C gives the current concept.

4. Contractor Responsibilities

The Contractor shall ensure that the System meets all appropriate safety and engineering requirements, and shall also ensure that:

4.1. The End-User's property (Table 1 and Appendices C-H) are integrated into the System. Materials in Appendix I are available for shielding if appropriate;

4.2. All items specified to be composed of mild steel, or any other metal that is subject to corrosion, shall be specified to be suitably coated, painted, or plated to prevent corrosion;

4.3. Any lead that is used for shielding shall be designed such that it is either enclosed or painted to prevent direct contact with the skin;

4.4. All fittings (screws, bolts, threads etc) shall be metric, unless required for compatibility with the End-User's existing equipment;

4.5. No component of the System shall exceed the floor loading capacity of the main hall of the reactor of 5000 kg/m^2;

4.6. All structures and supports shall be designed and engineered to all appropriate structural and civil engineering codes, including the national seismic construction regulations (Section 2.4), to withstand additional forces from peak ground acceleration of 0.25g (laterally) and 0.166g (vertically) such that they are in conformance with classification Class B Category II, as defined in IAEA-TECDOC-348 (Section 2.3);

4.7. The motor drives, encoders, and motor control systems specified shall be compatible with a major control software system for neutron beam instruments in use at other neutron beam centres;

4.8. All electronic components (semiconductors etc.) shall be designed to be placed outside the bunker wherever possible. Where electronics are placed inside the bunker, they shall be designed to be adequately shielded. Mechanical encoders are preferred to optical encoders for all motors;

4.9. A safety Programmable Logic Controller (PLC) and the required ancillary devices (e.g., last person out buttons; latching emergency stop buttons; status alarms, door interlocks) are specified. The Contractor shall design schematic logic such that no person may be present when the beam is on or become trapped within the bunker. This safety PLC and the schematic logic shall be compliant with IEC/EN 62061 (Section 2.2) and all other relevant regulations.

4.10. Any pressurized system conforms to the Moroccan pressure vessel code (Section 2.1).

4.11. The number and location of services to be provided by the End-User inside the bunker (power, signal cable, compressed air or gases, etc.) are specified.

4.12. Proposed factory and site acceptance tests for the System and major components are provided: suggested components are given in Table 3.

4.13. Full documentation to the End-User of the designs in electronic format at each (Table 4) is provided. Where computer aided design programs are used in design development, the Contractor shall supply the design in a form that can be readily imported into SolidWorks®.

4.14. The End-User receives the assistance necessary in their preparation of the safety case for approval for eventual installation of the System by providing all such information that is reasonably available to the Contractor and pertinent to the development of such a case.

4.15. Budgetary guidance is provided to the End-User for expected future procurement, manufacturing, and installation costs in the form of Opinions of Probable Cost, including suitable levels of contingency funds, that shall be refined at each design stage (see Table 4).

4.16. The Contract is performed following the milestones in Table 4. At each of the milestones 2, 4, and 6, the reports shall be supplied to the End-User and to IAEA in the level of detail described below. The End-User and IAEA shall reserve the right to submit all the materials provided by the Contractor to third parties for review.

4.16.1. Milestone 2 (Conceptual Design): drawings and a written report sufficiently developed to communicate the proposed final design concept, a list of all functions of the System and of all likely major components required to be procured or manufactured (with suggestions for make/buy decisions) together with their expected performance, identification of long lead time components, proposed future schedule for procurement, manufacture and installation, outline of an installation plan, Opinion of Probable Cost /Conceptual Estimate, and a description of identified interfacing issues between the End-User and the Contractor;

4.16.2. Milestone 4 (Preliminary Engineering Design): engineering calculations, drawings and a written description for each subsystem and major component in the System and their expected performances, make or buy decisions, lists of proposed materials for construction, preliminary spare parts list, updated estimate of costs and time for construction, proposed factory and site acceptance tests, updated list of interfacing issues, and a preliminary installation plan;

4.16.3. Milestone 6 (Detailed Engineering Design): a detailed specification, design, and layout for every component in the System suitable to be sent out to bid for manufacture, procurement, or assembly to a third-party, if required. It shall also include a list of materials for items to be constructed, possible suppliers and possible model numbers of equipment that may satisfy specifications, specification of control software requirements, spare parts list, updated estimate of costs and time for construction, final list of interfacing issues, and a detailed installation plan.

Table 1 – Items and utility services provided by the End-User

No.	Description	Notes
	Items	
1.	Collimator with sapphire filter	Stops down the neutron beam and filters it. See Appendix D.
2	Primary beam shutter with integrated, nitrogen-cooled Bi filter	Opens and closes the NB-1 beam at the edge of the biological shield. See Appendix E.
3	$3\theta_c$ neutron guide	See Appendix F.
4	Gamma spectrometer with Compton suppression with all required calibration standards, computer and software	Proposed principal detector component for PGAA. See Appendix G.
5	CCD and camera box	Proposed principal detector for NRAD. See Appendix H.
6	Computer, image processing software, and RAID storage system	For processing neutron tomographic images. Connected to the CCD by at most 10 m of cable.
	Utility Services	
1.	Single-phase AC power	220V, 50 Hz, plug type E.
2	Three-phase AC power	25-Amp service of 4-wire + ground, at 380 V, 50 Hz
3	Compressed air	dry service air at 10 bars pressure
4	Hoisting and lifting	Two cranes: one with 6-ton capacity, one with 3-ton capacity (see Appendix C, Figure C1 for limits of reach). Additional mobile lifting capabilities is available in the form of a “giraffe” with steerable wheels;
5	Networking and Internet connections	As required for the function of the System and connection to the internal networks and to the Internet;

Table 2 – Performance of the completed System

No.	Description
1.	Switch easily between PGAA and NRAD modalities; i.e. the required optics, sample tables, and detectors.
	For PGAA
2	Neutron background at detector position: - Beam ON: less than 150 cps, - Beam OFF: less than 20 cps,
3	Gamma dose rate at PGAA detector: - Beam OFF: less than 10 µSv/h,
4	Maximum sample dimension: 5 cm x 5 cm x 5 cm
5	Maximum sample weight: 10 kg
6	FOR NRAD
7	Maximum sample dimension: 80 cm x 100 cm x 50 cm
8	Maximum sample weight: 200 kg
9	Minimum spatial resolution: 200 µm.
10	Detector positions: two positions located at 5 and 6 m from the NB-1 exit
11	Fields of view: circular with diameter ranging from 8 to 20 cm

Table 3 – Suggested System Components

No.	Component	Details	Notes
		Common components	
1.	Beam stop	To achieve fields less than 10 microSv/h (gamma + neutron) behind it based on MCNP input from the End-User.	MCNP data will be supplied by the End-User. See Appendix D.
2.	Platform or platforms	Suitable to hold all objects such as the detectors, sample manipulators and chambers at beam height. The platforms must provide for suitable motion of the detectors, sample manipulators and chambers that are placed upon them as	

		required for functionality of the System. The platform(s) themselves may require translation or rotation beneath them.	
3	Neutron optics exchanger	A mechanism capable of switching the optics between PGAA and NRAD. It switches between (1) the neutron guide and (2) the L/D collimator exchanger and the primary flight tube. A vertical design is suggested due to reasons of space.	Fig. B1 shows a schematic.
4	Remote cameras	Placed inside the biological shielding capable of viewing the configuration of the System while the beam is one (e.g. neutron optics exchanger; sample table of NRAD)	Placed in negotiation with End-User
5	PLC Safety System	A qualified PLC (see Section 2.2) to provide overall safety logic for the System. It will monitor the shutter position, door interlock, emergency stop buttons, and provide a last person out system with appropriate alarms.	To be designed in conjunction with the End-User. See Appendix C, E.
6	Hardware Electronics	All necessary motors and drives, control electronics and crates to control and process data from the System	As recommended by Contractor
7	Control software	Specification of possible software required to setup, control and record scans and other operations of the System.	As recommended by Contractor
8	Fast shutter	A low-weight, fast shutter at the end of the primary flight tube and neutron guide that can open and close the neutron beam in less than ca. 1 second.	See Appendix B (Section B4, Fig. B1)
		PGAA-specific components (Appendix A)	
9	Irradiation chamber and sample holders	Suitably shielded, vacuum compatible irradiation chamber with means of introducing and holding samples in the beam and allowing for passage of neutron and gamma rays. Removable when in NRAD mode.	See Appendix A (Fig. A5)
10	Beam shapers	To reduce the beam dimensions onto the PGAA samples	See Appendix A (Fig. A4)
11	Neutron monitor	A low-efficiency neutron detector (gamma-insensitive) and its associated electronics.	Output to limit count times and to be recorded for scans.
		NRAD-specific components (Appendix B)	
12	Flight tubes	Two flight tubes to allow neutrons an evacuated flight path from the primary beam shutter to the sample area.	See Appendix B (Figs. B1, B2)
13	Convergent-divergent pinhole collimators and L/D exchanger	For different image resolutions. A means to switch between them and put the selected collimator in the beam is required.	See Appendix B (Figs. B3, B4)
14	Sample stage and manipulator	Must hold and manipulate the objects that are to be imaged.	Objects can be large and heavy See Appendix B, (Fig. B5)
15	Beam limiter	A motorized system for setting different beam sizes.	Automated System. See Appendix B (Fig. B8)
16	System for mounting of camera and lens holder on two translation tables	Two tables: one to move the lens and camera in a light tight box towards/away from the object being imaged (Fig. H3, left), and the second to moves the lens and camera inside the box towards/away from each other via a motorized translation system. (Fig. H3 right.)	Automated system see Appendix H.
17	Shielding for NRAD camera	Appropriate levels of neutron and gamma shielding to form quality images.	See Appendices B and H

Table 4 –Milestones

No.	Component	Details	Responsible
1	Kick-off meeting	Either a meeting for a minimum of 3 days at the End-User's premises at the Contractor's cost or meetings conducted virtually if international travel restrictions are in place.	End-User and Contractor
2	Conceptual Design Report	Submission to the End-User and to the IAEA of a finalised approach to delivery of the System.	Contractor
3	Review of Conceptual Design Report	Acceptance by the End-User and the IAEA leads to next step.	End-User and IAEA.
4	Preliminary Engineering Plan (PEP)	Submission of a preliminary engineering plan to the End-User and to the IAEA, sufficiently detailed to permit final design.	Contractor
5	Review of PEP	Acceptance by End-User and the IAEA leads to next step.	End-User and IAEA.
6	Detailed Design Report	Submission to the End-User and to the IAEA of final designs and documentation to a level sufficient for procurement, manufacture, and installation	Contractor
7	Critical Design Review	Acceptance by End-User and IAEA leads to end of Contract.	End-User and IAEA.