Expression of Interest (EOI 27544-AI) to participate in IAEA Technology Challenge: Digital image processing for the Improved Cerenkov Viewing Device (ICVD)

Who we are

The primary role of the **Department of Safeguards** (IAEA-SG) is to deter the proliferation of nuclear weapons. To do so, the Department applies various technical measures referred to as ‘safeguards’ to verify the correctness and the completeness of the declarations made by Member States about their nuclear material and activities. IAEA safeguards are an essential component of the international security system.

The **Division of Technical and Scientific Services** (SGTS) is responsible for providing scientific, technical and logistics support to the Operations Divisions of IAEA-SG, including: design, development, testing, calibration, installation and maintenance of safeguards equipment.

Within SGTS, essential objectives of the **Technology Foresight** activities are to identify and evaluate emerging technologies that improve the usability, effectiveness and efficiency of the instruments used in the field by inspectors, and to enhance the IAEA's capabilities to detect undeclared activities.

This challenge aims at improving the capabilities of an instrument routinely used by IAEA-inspectors to verify declarations related to spent fuel assemblies stored in cooling pools.

What we are doing

Cerenkov radiation is emitted when charged particles, such as electrons, travel through a transparent medium (water) faster than the speed of light in that medium (water). The visible result is a blue glow with strong UV spectral components.

Figure 1 - Cerenkov glow

The IAEA confirms the presence of spent fuel stored underwater by using the Improved Cerenkov Viewing Device (ICVD), which magnifies the image, filters out the visible light and intensify the UV light.

Figure 2 - ICVD

The ICVD is pointed down towards the top of the **fuel pins** (also called fuel rod, bundled together into **fuel assemblies**: for instance the assembly represented below counts 72 pins).

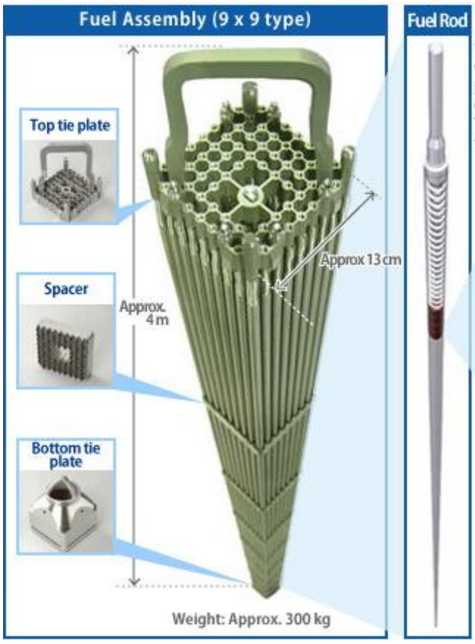

Figure 3 - Fuel assemblies and fuel rods (or fuel pins)

Figure 4 - Operator over a spent fuel storage pond (copyright Tokyo Times)

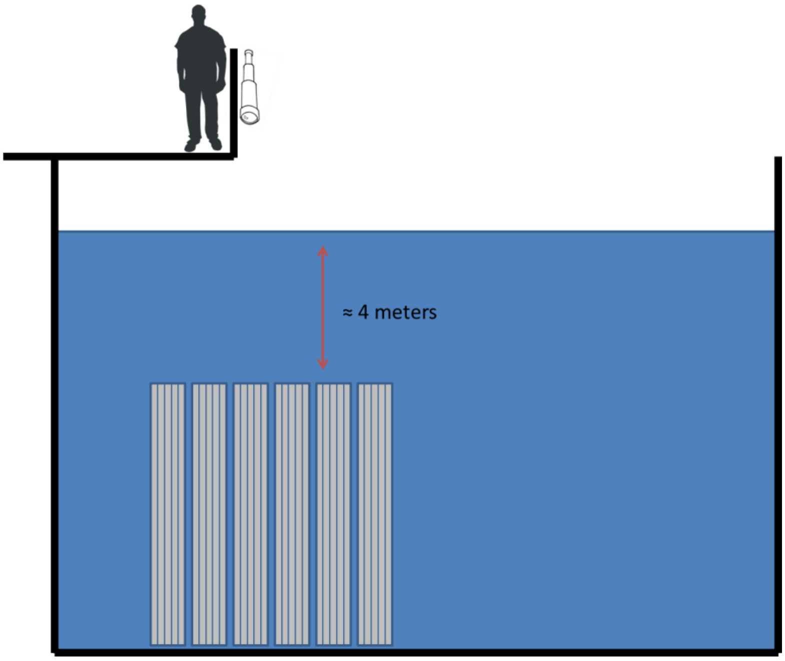

Figure 5 - Schematic showing the position of the inspector while counting underwater fuel assemblies

A small luminous dot can be seen ***between*** each pins of spent fuel; spent fuel pins are seen a dark spots. If a pin is missing the bright region is extended. (*Read carefully, most people initially think this is the opposite!*).

While this appears simple, in practice here are the following issues:

- **Images are noisy**: electronic noise (from the intensifier), vibrations (it is a handheld tele-lens), focusing problems, water turbulences (mostly from the surface) all degrade the theoretical resolving power of the instrument.

- **Images are feeble**: intensity of the Cerenkov light is inversely proportional to the time that fuel rods spent under water (this duration is called “cooling time”). The older the fuel is, the more difficult it becomes to see using an ICVD.

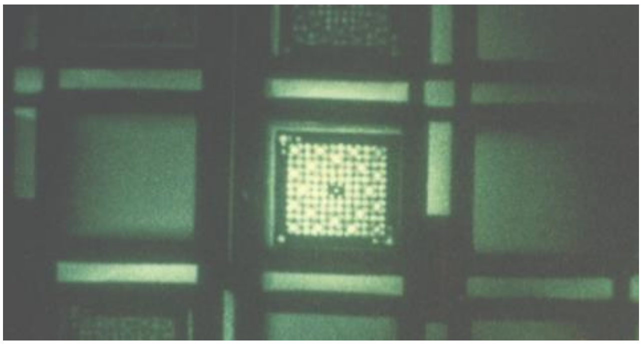

Figure 6 - 0.5 year cooling time

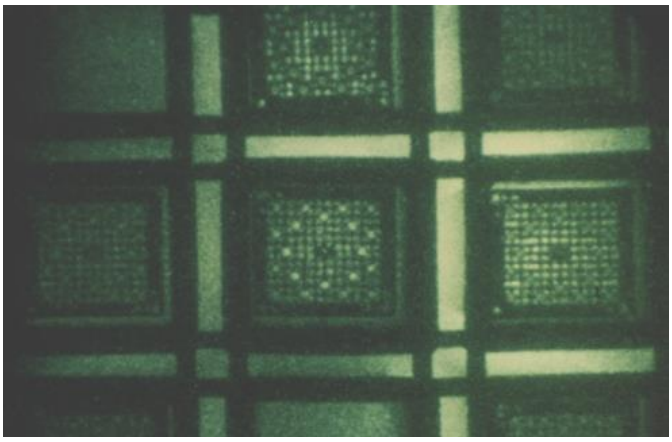

Figure 7 - 7 year cooling time

- **Images depend on the vertical alignment:** because Cerenkov light is emitted between the rods, it emerges from the top as heavily collimated: any small change in the vertical alignment translates into a variation of intensity. On the positive side, this helps discerning the near-neighbour effect, generated from fuel assemblies in close proximity to the assembly under examination and which is not collimated.

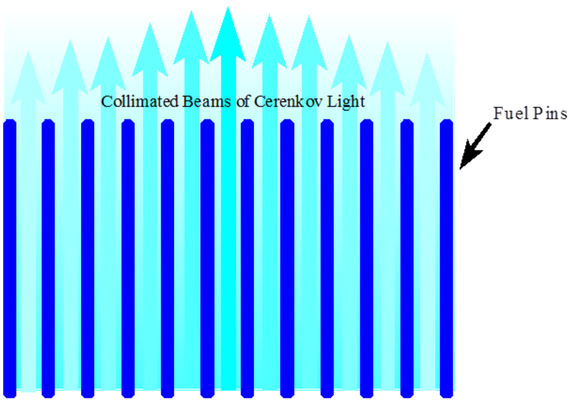

Figure 8 - Collimation effect of Cerenkov light

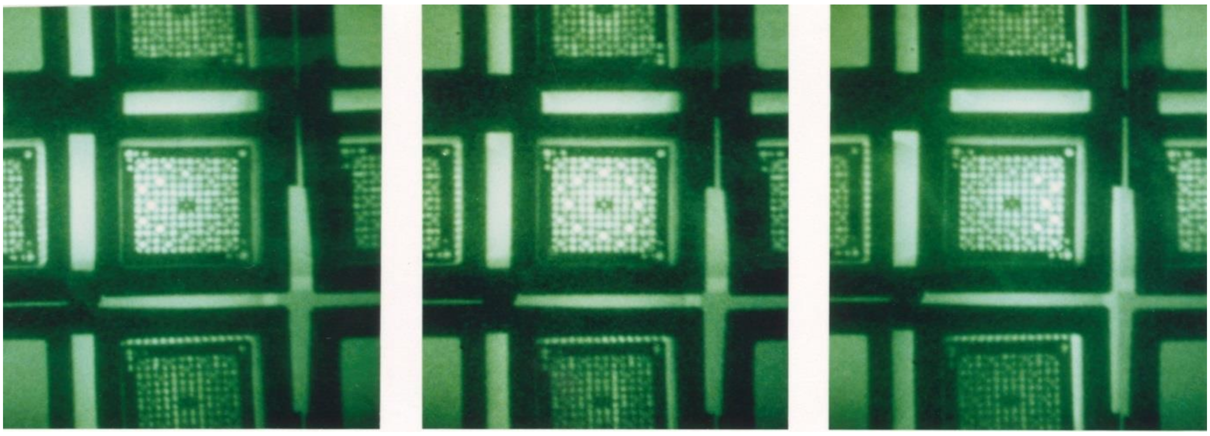

Figure 9 - Effect of proper vertical alignment (ICVD aligned in the center, slightly misaligned on the right and left pictures)

- **Images are numerous**: there are usually plenty of fuel arrays to count, so many that it may be difficult to keep track of which ones were already verified.

This challenge aims at creating a software that can process the videos captured through the eyepiece of an ICVD, and turn them into a single composite image with a better resolving power, thus improving the confidence of item counting.
Although not part of this challenge, a future objective will be to use the software in near real-time on a portable platform and participants are invited to provide an explanation of whether and how this can be achieved in the future.

What the work is about

After registering for the challenge, two categories of videos are made available to the participant; each category will be assessed separately.

- Category 1: Single fuel assembly video
The video captures a single fuel assembly. Some limited panning motion over the fuel assembly is used to properly align the pins with the Cerenkov Viewing Device and counter the collimation effect.
Results expected after processing:

> *R1. Create a single still composite image of the fuel assembly, combining the best frames for each pixel so that each fuel rod can be unambiguously seen by the viewer of the image.*
> *R2. Create a map of the fuel assembly showing the presence and absence of fuel rods, automatically providing a count of the fuel rods.*

- Category 2: Multiple fuel assemblies' video
The video captures a series of adjacent fuel assemblies. The panning motion is used not only to align the pins with the Cerenkov Viewing Device, but also to move from one assembly to another – covering one or several rows of fuel assemblies.
Result expected after processing:

R3. Similarly to R1, create a composite still image 2D panorama image of the whole area covered during the video, combining the best frames for each pixel so that each fuel rod can be unambiguously seen by the viewer of the image.
R4. Create a map of the complete area of fuel assemblies covered showing the presence and absence of fuel rods, automatically providing a count of the fuel rods.

Deliverables

Participants shall provide the following deliverables by the proposal due date indicated in the Challenge Roadmap:

- One or several results of the video processing (R1 to R4). Results can be submitted independently of each other. Partial results with significant scientific value will also be considered.
- A short description of the scientific principles used in the algorithm.
- A short description of the envisioned software (mode of operation, user interface, technical requirements, expected performances and limitations).

Challenge Roadmap

Please refer to the below Schedule for the Challenge milestones:

Milestones	Due Date (by COB ET)
Start of Challenge and training period (registration open):	May 6th, 2016
Registration End Date	July 28th, 2016
Start of the processing period:	July 29th, 2016
Proposals Due:	August 5th, 2016

Start of Challenge and training period (registration open): Participants send an email to a.ivanov@iaea.org indicating their intent to participate in the challenge and provide their contact details.

Registered participants will receive a link that includes training videos to be used for optimization, training and fine tuning of the algorithm. At any time during this period, participants may run their software against the data and revise their solutions.

Clarification questions may be addressed to the IAEA during this period (see email address below). The IAEA will respond and publish questions on a regular basis.

Processing period: At the start of the processing period, registered participants will be provided with new videos that they will need to process in order to achieve the results 1-4 as defined above. These results will be provided to the IAEA as part of their proposed solution.

Submission of the proposed solution: Participants shall provide the deliverables indicated above as part of their proposal.

Language: The Proposal shall be in the English language.

Length of Proposal: The Proposal shall be precise and concise. Catalogues, marketing or commercial documentation should be avoided, unless necessary for the Proposal.

Format of Proposal: Proposal should be submitted in electronic format unless otherwise stated (i.e. via e-mail) including all required documents (See Deliverables section above)

The Proposal shall be sent to the following IAEA contracting officer at the e-mail address: a.ivanov@iaea.org

Any communications/requests for clarifications related to these tender documents shall be addressed to: d.finker@iaea.org with a copy to a.ivanov@iaea.org

If electronic submission is not possible due to technical or size constrains, the Proposal can be split and submitted as several e-mail attachments. Please contact the IAEA contracting staff if you continue to have problems with your submission.

Evaluation: A panel of inspectors and IAEA experts will evaluate submitted results using the following criteria:

- Accuracy of the processing
- Clarity of the map representation
- Processing requirements to run the algorithm
- Scientific value of the algorithm
- User Interface and openness of the proposed mode of operation
- Required customization to meet IAEA's requirements

During this period, additional clarification questions may be sent by the IAEA to participants who submitted proposals.

Challenge outcome

- The participants with the best technical proposal in category 1: Single fuel assembly video will be offered an award of 5.000 euros
- The participants with the best technical proposal in category 2: Multiple fuel assembly video will be offered an award of 7.000 euros
- The winning participants of each category will have an opportunity to present their work at IAEA-Headquarter in Vienna
- Following the presentation, the winning participants will be invited to submit a fixed price proposal to customize the software for the IAEA, so that it can be integrated into the workflow of IAEA inspectors, and/or to transfer the software source-code to let IAEA customize the software on its own. In the event additional customization work is required, participants will be also invited to provide daily labour rates for future optional ad-hoc work.