ANNEX A

STATEMENT OF WORK FOR
FUSION OF BIOMETRICS SIGNALS FOR DIAGNOSING EMOTIONS

1.0 TITLE OF WORK:

Fusion of Vital Signals (EEG, ECG) with 3D Facial Images for Diagnosing Emotions

2.0 OBJECTIVES:

The objective is the design and development of a decision support system through fusion of biometrics signals for behavioural diagnostic applications. The system will be based on the automatic processing and the classification of data stemming mainly from Electroencephalogram (EEG), Electrocardiogram (ECG) recordings and tracking of 3D stereoscopic facial characteristics. This processing should provide automated diagnosis for the type of stressors that may influence the operational readiness of CF operators and should identify behavioural patterns with the aim of detecting hostile intend.

3.0 BACKGROUND:

Over the past 10 years, DRDC Toronto has developed a number of proprietary medical diagnostic technologies that include both 3D volumetric imaging and vital signs monitoring capabilities. Most recently, however, it has been identified that the above technologies have the potential to address:

- medical diagnostic applications,
- assessment of the type of stressors that may influence the operational readiness of CF operators, and
- identification of behavioural patterns with the aim of detecting hostile intend.

In particular, it is well established that a straightforward implementation of Biometric Technologies is not sufficient to identify behavioural/emotional patterns and/or stressors such as fear, anger, fatigue, etc, that may affect the CFs operators mental and psycho-physiological readiness.

Recent investigations at DRDC Toronto, however, on physiological and behavioural science have suggested that persons under stress will show various behavioural or physiological abnormalities. Though these signs can, at times, be detected by trained observers, they often go undetected and even when detected, are not quantified in any measurable way. This empirical observation suggests that vital signs sensors (ECG), an electroencephalography assessment of brain activities using EEG systems features, and tracking of 3D stereoscopic facial characteristics can provide quantifiable inputs in providing behavioural indicators, which leads to the requirement to develop an integrated system capability including vital signs, stereoscopic cameras and EEG to quantify stressors that may affect operational readiness and identify behavioural characteristics relevant with hostile intend.

As part of this quantifiable process, however, it is essential to develop the following signal processing functions that would allow for an automated decision support system through fusion of biometrics signals for behavioural diagnostic applications.

4.0 TASKS

PHASE 1 - SOFTWARE DEVELOPMENT REQUIREMENTS

4.1 Eye tracking software system

Monitoring systems of eye motion have been applied to many domains, such as human – machine interaction, or vigilance / mental state assessment, or product advertising. The requested software system development should be designed for estimation of eye motion parameters, requiring nono-occular of stereoscopic image data. Initially, the proposed system should be applied on acquired DRDC Toronto data in order to assess its basic capabilities than may be demonstrated at a later phase for real time usage. More specifically the requested software development must include the following functionalities:

4.1.1 Pupil diameter measurements

Pupil diameter is a physiologic indicator that may be measured with low degree of ambiguity, whereas the small characteristic time of the phenomenon does not impose high computational demands.
*Minimum Mandatory Technical Requirement***:** mono-ocular, low rate frame acquisition, using the standard image resolution provided by DRDC's 3D stereoscopic camera system.

4.1.2 Blink measurements

The rate at which a subject blinks, as well as the duration of blinks is an important indicator of the subject's psychological situation, as well as vigilance.
Blink measurements, as well as a number of the rest of eye measurements are based on the **iris detection**. Iris detection is usually proven more reliable than the easier to achieve pupil detection, since the iris is larger and therefore less frequently occluded by the eyelids. However, iris detection presents high complexity, since this object has weaker edge magnitude along the edge pixels with the sclera, as well it is usually partially occluded by the upper eyelid, as well as the eyelashes.
*Mandatory Technical Requirement***:** The phenomenon of eye blinking has a characteristic time of a few hundred milliseconds. Therefore, it will require intermediate rate of mono-ocular frame acquisition, with standard image pixilation provided by DRDC's 3D stereoscopic camera system.

4.1.3 Lid measurements

Mandatory Technical Requirement: The instantaneous speed of eyelid closing and opening must be measured, so that their correlation with the subject's psychological status can be studied. The very fast characteristic time of eyelid motion imposes very high demands for real time video frame processing, up to 30 frames per second , as provided by DRDC's 3D stereoscopic camera system.

4.1.4 Eye motion tracking - Saccade measurements

Saccades are the principal movements for moving the eye to different locations on the visual scene. Saccades usually take 100 – 300 ms to initiate, while the movement is completed within 30 to 120 msec, depending on the angle traveled by the eye. The eye remains fixed to the new location for about 300 to 600 msec (fixation period), during which the processing of the visual image takes place. Eye motion and saccadic measurement detection, should be based on the iris detection, as well as the pupil detection. Iris detection is usually proven a more reliable indicator than the easier to achieve pupil detection, since the iris is larger and therefore less frequently occluded by the eyelids.
*Mandatory Technical Requirement***:** The characteristic time of the phenomenon of saccadic movement will require intermediate to high rate of mono-ocular frame acquisition, with standard image pixilation, as provided by DRDC's 3D stereoscopic camera system.

4.1.5 Eye gaze direction

This is an indicator that has traditionally been related to the subject's emotional state. The direction of eye gaze should be calculated in real time, using the information from the stereoscopic set of cameras. The 3D eye reconstruction, combined with the iris and/or pupil detection, should allow for the determination of the direction of eye gaze.
Mandatory Technical Requirement: The characteristic time of the phenomenon of eye gaze direction will require intermediate to high rate of stereoscopic frame acquisition, with standard image pixilation, as provided by DRDC's 3D stereoscopic camera system.

4.1.6 Training the eye tracking software system

The eye tracking software system should be trained with a number of individuals and a number of emotional states, so that a generic labeling is possible that maps arbitrary face expressions of any person to a number of predefined emotional states.
For this reason, a number of images should be used to provide a train set for the initial estimation of the system's parameters, as well as their allowed range for robust eye motion detection.
Eye motion calculated parameters from a number of individuals with artificially induced behavioral issues will be used to train and test the possibility of automatic classification of behavioral issues.

4.2 3D facial feature tracking: Determination of parameters of a facial model

The facial characteristics describe a person's emotional state. Therefore, the extraction of facial characteristics, gestures and their change from a series of face frames, could lead to correlation with predetermined emotional states.
The requested signal processing functionalities must employ a generic 3D face model as well as a number of characteristic facial points whose position can generate a number of frequent facial expressions. The points of the 3D facial model should present higher concentration on regions like eye corners, lips, nose and eye browses.

4.2.1 Determination/verification of the eye motion parameters

The determined parameters of a facial model should be used to calculate some of the eye motion parameters that were described in the previous section 4.1, such as blink parameters and eye lid motion parameters. The calculation will be used as verification between the two independent system modules.

PHASE 2 - SOFTWARE IMPLEMENTATION and TESTING REQUIREMENTS

4.3 Training the facial model

The facial model has to be trained with a number of individuals and a number of emotional states, so that a generic labeling is possible that maps arbitrary face expressions of any person to a number of predefined emotional states.
Eye motion calculated parameters form a number of individuals with artificially induced behavioral issues will be used to train and test the possibility of automatic classification of behavioral issues. For this purpose, a number of well established classification techniques should be tested, such as: k-nearest neighbor (k-NN), artificial neural networks (ANN), fuzzy c-means (FCM), artificial immune system (AIS), support vector machines (SVM).

The investigation should experiment with a number of vertices of the 3D face model to establish the minimum required number of vertices that produce acceptable high classification results.

4.4 Fusion of facial model parameters and bio-signals

The investigation should fuse eye motion parameters and 3D facial model parameters with the most essential bio-signals, such as ElektroEncephalograph (EEG) and ElectroCardiograph (ECG), according to the following aspects:

4.4.1 Determination of the subject's emotional state and behavioral issues

The ECG and EEG bio-signals may include additional information that could be used to classify the subject's emotional and behavioral state. Therefore a number of bio-signal descriptors should be considered, such as heart rate (for the ECG), spectral power according to specific frequencies. The bio-signal descriptors will be calculated and fed into the classifier, along with the facial model parameters and the eye motion parameters. The training and testing phase will determine if the addition of the bio-signals descriptors will improve the accuracy of the classification process.

4.4.2 Fusion of facial model parameters and bio-signals

If the bio-signals prove to increase the overall accuracy of classification of the subject's emotional state and behavioral issues, the software development should include a module that will allow for the simultaneous view of the synchronized values of the facial model parameters, eye motion parameters and bio-signals descriptors or bio-signal values. The Fusion module should be based on fast OpenGL or other similar graphics libraries and it will provide sophisticated user interface.

4.5 Development of an automated classification system

The classification system that will result from the previous developments, should be automated and should consist of two main modules: a) the pre-processing and feature extraction module, b) the feature selection module and the classification module.
The system should be tested on EEG/ERPs data of normal subjects as acquired by the DRDC Toronto. The system should be able to classify the subjects' reactions under different scenarios during the experimentation procedure such as subjects under stress or relaxing, etc. These different situations (classes) will be finalized by DRDC Toronto and the data sets will be available to successful bidders. For each class, a minimum of 20 subjects is a pre-requested acquisition parameter.

4.6 Application of the classification system to discriminate different entities

The performance of the system will be further tested by incorporating within the developed system other features related with the behaviour of the subjects such as features obtained by processing facial images from real time video recordings or any other physiological recording (as they will be provided by DRDC Toronto). In this development the performance of the system will be tested in terms of possible improvement of the classification rate.

<u>PHASE 3 - FINALIZATION OF THE SYSTEM</u>

4.7 Testing of the classification system to differentiate psycho-pathologic entities – Finalization of the system

In the final state of development, the system automation, throughout the above 4.5 and 4.6, should be further investigated towards discrimination of psycho-pathologic entities. In particular, the system will be applied on data (ERPs) provided by DRDC Toronto in order to test its performance in these kind of data. Along these lines, the development in 4.7 should be focused on the classification of subjects under stress from normal controls using the developed system, the identification of any required modification on the system and the finalization of the classification system.

5.0 DELIVERABLES:

Phase 1:

1) Development of an Eye tracking software system, as defined in 4.1

2) Development of an 3D facial feature tracking, as defined in 4.2

DELIVERABLES: Software and report

Phase 2:

3) Training the facial model, as defined in 4.3

4) Development of a Fusion of facial model parameters and bio-signals, as defined in 4.4

5) Development of an automated classification system, as defined in 4.5

6) Application of the classification system to discriminate different entities, as defined in 4.6

DELIVERABLES: Software and report

Phase 3:

7) Testing of the classification system to differentiate psycho-pathologic entities – Finalization of the system, as defined in 4.7.

DELIVERABLES: Report

There will be a review at the end of each phase. The contractor will have to provide evidence of satisfactory completion of the current phase before permission to proceed to the next phase of the project will be granted.

6.0 GOVERNMENT FUNDED EQUIPMENT:

The Scientific Authority will ensure that the contractor has access, if needed, to existing facilities and equipment/software, such as ECG, 128-channel EEG, as required, as well as the technical expertise of the scientists, engineers and technicians at DRDC Toronto. All equipment, including software purchased under the contract, belongs to the Government of Canada and will be returned to the Scientific Authority.