Chapter 5 – CONCLUSIONS

The NATO/RTO HFM-090/TG-25 was established in response to the NATO/RTO HFM ET 007 which identified the lack of suitable information for injury assessment of the anti-vehicle mine threat. Furthermore, the task group was asked to help the STANAG 4569 TOE to develop an injury assessment methodology for the qualification of the protection of light-armoured and logistic vehicles from (blast) landmines.

The main conclusions and remarks of the HFM-090/TG-25 work are summarized below, while reference is made to the separate chapters for detailed information on the injury assessment and the test methods.

- Injury criteria and tolerance levels were proposed to assess the body regions most vulnerable to a blast mine strike under a vehicle. The tolerance levels established for each body region are considered to represent low risk of life-threatening and disabling injuries (10% risk of AIS 2+). The proposed mandatory injury criteria are summarized per body region:
    - Lower leg and foot/ankle — Peak lower tibia compression force
    - Thoraco-lumbar spine — Dynamic Response Index (DRIz)
    - Cervical spine (and head) — Compression force
      Peak flexion bending moment
      Peak extension bending moment
    - Non-auditory internal organs — Chest wall velocity predictor (CWVP)

  Background information and tolerance levels can be found in Chapter 3.
- The Abbreviated Injury Scale (AIS) is a measure of injury severity (including the risk of fatal injuries) as opposed to a measure of impairment or disabilities. Therefore, the outcome of the injury assessment provides information on the medical condition as opposed to the incapacitation (short or long term) or on the recoverability of the occupants.
- The injury criteria (or injury risk models) proposed herein were originally developed for motor vehicle and aircraft safety and were based on other loading conditions (lower amplitude at longer durations) than those occurring during a mine strike under a vehicle. They were, and still are, however, the most appropriate available for the mine loading conditions.
- The method proposed includes injury criteria for the body regions considered most vulnerable to an AV blast mine strike. These body regions were determined with the best available information (few real incident reports and full-scale testing experience). Of course, other body regions can be injured as well during a real mine strike. Additionally, psychological effects will also occur and influence the incapacitation of the occupant.
- The tolerance levels were determined conservatively.
- There is no proposal for assessment of injuries caused by fragments, detonation products and loose objects. So far, it has been assumed that injury risk constituted by these products was minimal due to vehicle integrity and prevention of flying objects.
- It is assumed that permanent auditory injuries will not occur when wearing proper hearing protection. Therefore, no pass/fail criterion for auditory injuries has been proposed. It is strongly recommended to wear proper hearing protection to minimise risk of temporary or permanent auditory injuries from a mine detonation.
- The TG-25 also discussed a protocol for test set-up and injury assessment, and prescribed the use of the Hybrid III 50th percentile anthropomorphic test device (ATD) together with pressure

sensors. The test protocol is presented to the STANAG 4569 and more detailed information has been presented in Chapters 4 and 5.

- The standard Hybrid III has been developed for frontal car impact. It is recently the best available surrogate for the vehicle mine protection testing (or research) area as well. The standard Hybrid III lower leg model is stiff and therefore results in higher tibia peak loads than expected in a human. This means that using the standard Hybrid III leg results in a conservative method when used for injury predictions.
- The method described by the TG-25 is to be used as pass/fail assessment for occupant safety in qualification trials of mine protected vehicles, according to the STANAG 4569. It is also possible to estimate the risk of lower leg and spine injury, based on the measured ATD response, since risk curves are available for these body regions.

A new team needs to be assembled to carry the mandate of TG-25 further, but in the meantime, the recommendations made by the TG-25 stand. They reflect the best knowledge available at this point. They are the result of an honest best effort and are the best available at the time of publication.

What comes after TG-25

TG-25 was assembled by NATO-RTO-HFM ET 007 and STANAG 4569 in response to their need. It brought together a team of professionals from several branches of science, engineering and medicine.

A lot of the TG-25 work was based on information available in literature as well as real accidents and full-scale test data. Some technical and medical assumptions were made to define a simple and realistic injury assessment method for vehicle mine protection testing. Gaps still remain in the method, and further research is required to fill some of them. Based on the current status, recommendations for future work are given below:

- Improvement of lower leg injury assessment (criteria, tolerance level, mechanical models);
- Improvement of spinal injury assessment (criteria and tolerance levels);
- Improvement of neck and head injury assessment (criteria and tolerance levels);
- Improvement of pressure measurement device and injury assessment;
- Expansion validation of experimental and numerical models;
- Improvement of the test methodology; and
- Exploration of actual incidents both from a technical and medical standpoint.

There is also a need to assemble a new team focusing on different types of threats to vehicle occupants such as the improvised explosive devices (IED) and shaped charges. This team, which is already designated as HFM-148/RTG and which will start in 2006, can follow the HFM approach as presented in this report.