AVT-321 Technical Course

Unified Tactical Missile Kinetic Performance Model

organized by the
Applied Vehicle Technology Panel
to be held at

NATO School Oberammergau, Oberammergau (GER)
on 04 – 06 June 2019

NATO Joint Warfare Center, Stavanger (NOR)
on 27 – 29 August 2019

German Aerospace Center (DLR), Washington D.C. (USA)
on 10 – 12 September 2019

Lancaster University Center, Lancaster, CA (USA)
on 17 – 19 September 2019

This Technical Course is open to citizens from
NATO Nations, Australia, Finland and Sweden

Enroll on-line at

All presentations and discussions will be held in English

NATO needs to maintain a capability edge over potential adversaries with new and upgraded missile systems. Concept definition is the first step towards a new missile system. Mission requirements will determine the size and performance of a system. Both are strongly related to the type and size of the propulsion sub-system.

Currently, to perform conceptual design, military users, procurement agencies and defense contractors in NATO nations use individual proprietary models and different data bases. This leads to non-consistent results and is hindering collaboration.

A task group formed by the Applied Vehicle Technology Panel of NATO's Science and Technology Organization has leveraged the expertise of defense contractors, research organizations and governmental agencies from five NATO nations to create a unified tactical missile kinetic performance model.

The students learn how to select a surface or air-launched mission trajectory and define the size and shape of a missile body. They learn how to define the appropriate propulsion system choosing between

- a Solid Propellant Rocket motor, which is still the most common choice today.
- a Throttleable Ducted Rocket, an advanced air-breathing system for missions demanding long range and sustained high speed
- or potential future candidates for tactical missile propulsion like a rocket motor with gelled fuel, a hybrid rocket motor or a Solid Fuel Ramjet

Technical Course Director

Dr. Norman Hopfe, Germany, Bayern-Chemie GmbH

Speakers

Dr. Norman Hopfe, Germany, Bayern-Chemie GmbH
Mr. Jason Mossman, USA, AFRL
Dr. Erland Orbekk, Norway, NAMMO
Mr. Ronald Veraar, Netherlands, TNO
Dr. Helmut Ciezki, Germany, DLR

ARRIVAL DAY (Monday) (evening prior to workshop)

18:00 - 19:00	**Arrival and Evening Registration** Registration

Day 1 (Tuesday) – Session 1: Foundations

07:30 - 08:45	**Registration** Name tags, course material, information package
09:00 - 09:10	**Welcome Speech** by host facility representative What does the facility do?
09:10 - 09:15	**Facility Campus** opportunities and regulations Where is what on the facility campus (classroom, lunch location etc.)? What regulations are on the campus (facility card, restricted areas, photography regulations etc.)?
09:15 - 09:20	**Welcome Speech** by STO/AVT representative What does the STO/AVT do?
09:20 - 09:30	**Introduction students** What is your name? Where do you work? What experience do you have in that field? What do you expect from this workshop?
09:30 - 09:50	**Opening (Dr. Norman Hopfe)** Introduction of the presenters, people and companies/research institutes involved in the project, topic explanation, schedule introduction and student's questions/requests
09:50 - 10:00	Course picture

---------- Coffee ----------

10:30 - 12:00	**Missile study initialization (Mr. Jason Mossman)** • General description of the current process structure • Pro/Con of the current way forward • Explanation on a known scenario • Support of the standardizes software tool of the Technical Course during this process from a working objective point of view • Benefit of a standardized tool

---------- Lunch ----------

Day 1 (Tuesday) – Session 2: Missile systems

13:00 - 14:30	**Missile system** **(Dr. Helmut Ciezki, Dr. Norman Hopfe, Mr. Jason Mossman)** • General build-up of a missile including limitations related to the Software Tool • Definition of a mission • Influence of different engine types to other missile subcomponents • Overview of existing missile systems • Operational matrix of the different engine types • Testing of different engine types

---------- Coffee ----------

15:00 - 16:30	**Introduction of the Software Tool (Dr. Norman Hopfe)** • General Software Tool structure overview • System engineering and analyzing aspect • General limitations and modelling status of the Software Tool • User Interface (GUI) of the Software Tool • Disclaimer
18:00	---------- Ice Breaker ---------- City restaurant

Day 2 (Wednesday) – Session 3: Putting it into practice

08:30 - 08:40 **Summary Day 1 (Dr. Norman Hopfe)**

Wrap up from what happened yesterday

08:40 - 10:00 **Software Tool Content (Dr. Norman Hopfe, Mr. Jason Mossman, Dr. Erland Orbekk)**

- General Software Tool performance/simulation overview
- Explanation of the booster module including Tandem Booster
- Introduction of the Solid Rocket Motor (SRM)
  - Function vs. modelling status
  - General capabilities
  - General inputs (e.g. grain and propellant type) and impact on thrust profile, range, trajectory, smoke classification
  - Description of different grain and propellant types
  - Limitations and non-modelled aspects
  - Demonstration of an example
- Introduction of the Thrust Vector Control (TVC)
  - Pro/Con of a TVC
  - Impact on the nozzle and performance and on the trajectory
- TRL for the different engine types

---------- Coffee ----------

10:30 - 12:00 **"Select an engine" I (Dr. Norman Hopfe, Dr. Erland Orbekk, Mr. Ronald Veraar)**

- Introduction of the Solid Fuel Ramjet (SFRJ) and Throttleable Ducted Rocket (TDR)
  - General operational regime and operational limitations
  - General description of the working principle
  - Fuel type, gas generator propellant, characteristics
  - Air intake sizing
  - Control logic and impact
  - Aerodynamic impact and influence
- Explanation of an integral booster including impact and types
- Explanation of the Air Intake module (AI)
  - Introduction of different types
  - Impact on overall performance, maneuvering, stability
  - Modelling status and limitations
- Demonstration of an example

---------- Lunch ----------

Day 2 (Wednesday) – Session 4: Putting it into practise

13:00 - 14:00 **"Select an engine" II (Dr. Helmut Ciezki, Dr. Erland Orbekk)**

- Introduction of the Gelled Propellant Rocket Motor (GRM) and Hybrid Rocket Motor (HRM)
  - Potential operational regime and operational limitations
  - General description of the working principle
  - Fuel and propellant type, characteristics
  - Throttling capabilities
  - Control logic and impact
- Status and readiness as potential future tactical missile engines
- Demonstration of an example

14:00 - 15:00 **Software Tool I (Dr. Norman Hopfe)**

- Introduction of the Software Tool
- Starting the GUI
- Explanation of the different modules and inputs
- Explanation of the GUI plots
- Explanation of the stored results data files (Excel, Matlab)
- Re-modelling the demo cases as user-defined scenario

---------- Coffee ----------

15:30 - 17:00 **Software Tool II (Dr. Norman Hopfe)**

- Follow-on of Session "Software Tool I"
- Tool Explanation by the SRM and TDR examples
- Explanation of the SFRJ, GRM and HRM

18:00 ---------- Course Dinner ----------
City restaurant (non-hosted)

Day 3 (Thursday) – Session 5 + 6: **Practice**	
08:30 - 08:40	**Summary Day 2 (Dr. Norman Hopfe)** Wrap up from what happened yesterday
08:40 - 10:00	**Practice I (all speakers)** Students work with the Software Tool under instruction of the speakers Specified exercises With in-service engine types and aspects Generating a missile, preparing the simulation and results Analyzing the outcome of the exercises and performance Presentation and discussion of the students results
	---------- Coffee ----------
10:30 - 12:00	**Practice II (all speakers)** Follow-on of Session “Practice I” Exercises with all engine types Comparing of different solutions Analyzing the outcome Presentation and discussion of the students results
	---------- Lunch ----------
13:00 - 14:00	**Practice III (optional)** optional Session “Practice III” (if requested)
	---------- Coffee ----------
14:15 - 15:30	**Closing discussion** Discussion of the “Practice” sessions Answering students questions Code availability (download) and distribution Comments and feedback Expected or additional features in the code missed from the user perspective
15:30 - 16:00	**Closing remarks and departure** Course material and hands out Questionnaire Technical Course content Questionnaire organization and host facility Out-processing