# Dynamic flight-to-ground duplication of atmospheric entry stagnation point flows

*A Data Management Plan created using DMPonline.be*

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**Project abstract:**

The study of atmospheric entries is a key topic that both enables the exploration of space and unlocks the benefits of spaceflight and space research here on Earth. Despite its crucial role, the entry environment remains poorly understood and replicating it on Earth is difficult. Research is needed to develop more efficient Thermal Protection Systems (TPSs), as well as to solve the problem of space debris. The Von Karman Institute for Fluid Dynamics uses plasma facilities to recreate the extreme conditions encountered at the stagnation point of an entry vehicle. The current methodology to reproduce flight conditions in a ground facility has two downsides: (1) it is a costly hybrid numerical/experimental procedure and (2) it is limited to the duplication of a single flight trajectory point. This project aims to use data-driven methods to simplify the methodology, a necessary step towards dynamic testing, i.e. reproducing entire sections of the entry trajectory in a single test. Doing so replicates the heating history in a ground test, leading to more efficient TPS designs, and a better assessment of space debris demisability. As an application, the resulting method will be applied to the innovative re-entry mission under development by Aether, KU Leuven's Student CubeSat Team. Aether aims to create a CubeSat platform that enables the return of samples and experiments from LEO, reducing the cost for experiments in space for sectors that require this capability.

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# FWO DMP (Flemish Standard DMP)

**1. Research Data Summary**

**List and describe all datasets or research materials that you plan to generate/collect or reuse during your research project. For each dataset or data type (observational, experimental etc.), provide a short name & description (sufficient for yourself to know what data it is about), indicate whether the data are newly generated/collected or reused, digital or physical, also indicate the type of the data (the kind of content), its technical format (file extension), and an estimate of the upper limit of the volume of the data.**

| | | | | Only for digital data | Only for digital data | Only for digital data | Only for physical data |
|---|---|---|---|---|---|---|---|
| Dataset Name | Description | New or reused | Digital or Physical | Digital Data Type | Digital Data format | Digital data volume (MB/GB/TB) | Physical volume |
| | | *Please choose from the following options:*<br>• Generate new data<br>• Reuse existing data | *Please choose from the following options:*<br>• Digital<br>• Physical | *Please choose from the following options:*<br>• Observational<br>• Experimental<br>• Compiled/aggregated data<br>• Simulation data<br>• Software<br>• Other<br>• NA | *Please choose from the following options:*<br>• .por, .xml, .tab, .csv,.pdf, .txt, .rtf, .dwg, .gml, …<br>• NA | *Please choose from the following options:*<br>• <100MB<br>• <1GB<br>• <100GB<br>• <1TB<br>• <5TB<br>• <10TB<br>• <50TB<br>• >50TB<br>• NA | |
| Plasmatron experimental data (previous test campaigns) | VKI 'Plasmatron' plasma wind tunnel test campaigns from previous research. Processed into Plasmatron experimental database of test conditions | Reuse existing data | Digital | Observational/Experimental | Raw data:<br>• .tdms<br>• .tdms_index<br>Processed into:<br>• .xlsx<br>• .pkl | < 100 GB | NA |
| Plasmatron experimental data (new test campaigns) | Outputs of new test campaigns in the VKI 'Plasmatron' plasma wind tunnel. Processed into Plasmatron experimental database of test conditions | Generate new data | Digital | Observational/Experimental | Raw data:<br>• .tdms<br>• .tdms_index<br>Processed into:<br>• .xlsx<br>• .pkl | < 100 GB | NA |
| ROVT computations | Re-entry trajectories computed with the VKI 'ROVT' code | Generate new data | Digital | Simulation data | • .mat<br>• .stl | < 1 G | NA |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Stagline computations | (pseudo-)1D CFD analyses along stagnation line of hypersonic re-entry vehicles (incl. processing into database of flight conditions) and subsonic test probes. | Generate new data | Digital | Simulation data | • .mat<br>• .dat<br>• .csv | < 100 G | NA |
| LHTS methodology data processing code | Data handling/processing codes (Matlab, Python) used in the LHTS flight-to-ground duplication methodology, from ROVT simulation to hypersonic Stagline simulation of trajectory points to subsonic Stagline simulation | Generate new data | Digital | Software | • .mat<br>• .py | < 100 MB | NA |
| Plasmatron data readout code | Universal data processing code (Python) for Plasmatron experiments | Generate new data | Digital | Software | • .py | < 100 MB | NA |
| High fidelity hypersonic CFD | 2D/3D CFD analyses of hypersonic/subsonic flows performed with the SU2 code | Generate new data | Digital | Simulation data | • .su2<br>• .csv<br>• .vtu<br>• .dat | < 1 TB | NA |

**If you reuse existing data, please specify the source, preferably by using a persistent identifier (e.g. DOI, Handle, URL etc.) per dataset or data type:**

Dataset name: '*Plasmatron experimental data (previous test campaigns)*'
Several sources:

- Raw data files in VKI repository, supplemented by notebooks of test engineer
- Tabulated data in publications
  - Viladegut Farran, PhD thesis, Assessment of gas-surface interaction modelling for lifting body re-entry flight design, 2017, http://hdl.handle.net/10803/461893
  - Sakraker, PhD thesis, Aerothermodynamics of Pre-Flight and In-Flight Testing Methodologies for Atmospheric Entry Probes, 2016, https://hdl.handle.net/2268/194601
  - Helber, Material response characterization of low-density ablators in atmospheric entry plasmas, 2016, ISBN 978-2-87516-098-0

**Are there any ethical issues concerning the creation and/or use of the data (e.g. experiments on humans or animals, dual use)? Describe these issues in the comment section. Please refer to specific datasets or data types when appropriate.**

- No

**Will you process personal data? If so, briefly describe the kind of personal data you will use in the comment section. Please refer to specific datasets or data types when appropriate.**

- No

**Does your work have potential for commercial valorization (e.g. tech transfer, for example spin-offs, commercial exploitation, …)? If so, please comment per dataset or data type where appropriate.**

- No

**Do existing 3rd party agreements restrict exploitation or dissemination of the data you (re)use (e.g. Material/Data transfer agreements/ research collaboration agreements)? If so, please explain in the comment section to what data they relate and what restrictions are in place.**

- Yes

The dataset: '*Plasmatron experimental data (previous test campaigns)*' may contain test data from commercial test campaigns between the VKI and third parties, not meant for dissemination, depending on the contract in place.

**Are there any other legal issues, such as intellectual property rights and ownership, to be managed related to the data you (re)use? If so, please explain in the comment section to what data they relate and which restrictions will be asserted.**

- No

**2. Documentation and Metadata**

**Clearly describe what approach will be followed to capture the accompanying information necessary to keep data understandable and usable, for yourself and others, now and in the future (e.g., in terms of documentation levels and types required, procedures used, Electronic Lab Notebooks, README.txt files, Codebook.tsv etc. where this information is recorded).**

| Dataset Name | Documentation |
|---|---|
| Plasmatron experimental data (previous test campaigns) | Tabulated data from published references is accompanied by a README.txt file explaining exact location of tables and other relevant information from the source. This data is collected into an .xlsx file (with indication of units of measurement). Raw data from VKI repository is accompanied by log.xlsx file as is customary at VKI, listing relevant information (experimental campaign, facility operator, probes used, targeted facility operating conditions, remarks/issues during experiment). Any missing entries are complemented where possible by test engineer notebooks. |
| Plasmatron experimental data (new test campaigns) | Raw data files are accompanied by log.xlsx file (see above). |
| ROVT computations | ROVT input settings are listed for each trajectory simulation in a config.xlsx file. |
| Stagline computations | Stagline input conditions/settings are stored in input files accompanying each simulation. Each simulation has corresponding entries in 2 .csv files:<br>• freestream.csv listing freestream conditions, corresponding ROVT trajectory point<br>• config.csv listing mesh settings, boundary conditions |
| LHTS methodology data processing code | All scripts/functions have inline documentation. Higher level directories have README.txt files explaining how to use the code. The code is maintained on VKI's github server as part of the ROVT code, with its own README.md file. |
| Plasmatron data readout code | Same approach as for LHTS methodology code (above). |
| High fidelity hypersonic CFD | Geometry information, boundary conditions, mesh settings for each simulation kept in README.txt files. |

**Will a metadata standard be used to make it easier to find and reuse the data? If so, please specify (where appropriate per dataset or data type) which metadata standard will be used. If not, please specify (where appropriate per dataset or data type) which metadata will be created to make the data easier to find and reuse.**

- No

#### 3. Data storage & back-up during the research project

**Where will the data be stored?**

All datasets, except the datasets listed below, are stored on the KU Leuven Onedrive for Business Cloud storage.
Stored/maintained on the VKI Github server:

- LHTS methodology data processing code
- Plasmatron data readout code

This storage solution is chosen because of the need for VKI students/staff to access and use the codes, and is common practice at VKI.

**How will the data be backed up?**

KU Leuven standard back-up options are used for datasets in KU Leuven storage. The following datasets are additionally stored on the VKI on-site data storage infrastructure:

- Plasmatron experimental data (previous test campaigns)
- Plasmatron experimental data (new test campaigns)
- Stagline computations
- High fidelity hypersonic CFD

**Is there currently sufficient storage & backup capacity during the project? If yes, specify concisely.**
**If no or insufficient storage or backup capacities are available, then explain how this will be taken care of.**

- Yes

KU Leuven Onedrive for Business storage has 2 TB of space, sufficient for the needs of the project.

**How will you ensure that the data are securely stored and not accessed or modified by unauthorized persons?**

The chosen storage solution is sufficient with regards to the confidentiality needs of the project, as indicated by the KU Leuven guidelines.

**What are the expected costs for data storage and backup during the research project? How will these costs be covered?**

The chosen solution (Onedrive for Business) is free for KU Leuven staff/students.

**4. Data preservation after the end of the research project**

**Which data will be retained for at least five years (or longer, in agreement with other retention policies that are applicable) after the end of the project? In case some data cannot be preserved, clearly state the reasons for this (e.g. legal or contractual restrictions, storage/budget issues, institutional policies...).**

According to the KU Leuven RDM policy, all datasets will be preserved for at least 10 years.

**Where will these data be archived (stored and curated for the long-term)?**

The datasets will be archived on the KU Leuven Research Data Repository (RDR), except for the developed codes (' *LHTS methodology data processing* code' & ' *Plasmatron data readout code*'). These will be kept, maintained and further developed on the VKI Github server.

**What are the expected costs for data preservation during the expected retention period? How will these costs be covered?**

The datasets are expected to be small enough such that preservation in the KU Leuven RDR is free. Costs for maintaining the VKI Github server are covered by the VKI.

**5. Data sharing and reuse**

**Will the data (or part of the data) be made available for reuse after/during the project? In the comment section please explain per dataset or data type which data will be made available.**

- Yes, in a restricted access repository (after approval, institutional access only, …)

The dataset '*Plasmatron experimental data (previous test campaigns)*' contains proprietary data from commercial experimental campaigns at VKI. Identifying information will be removed from the metadata to ensure anonymity of the test campaign. The developed codes ('*LHTS methodology data processing code*' & '*Plasmatron data readout code*') are considered VKI proprietary codes and will be made available only with approval from the VKI.

**If access is restricted, please specify who will be able to access the data and under what conditions.**

The developed codes ('*LHTS methodology data processing code*' & '*Plasmatron data readout code*') are property of the VKI and cannot be made available without approval and authorization from the VKI, as evaluated by its research coordinators. Access is granted upon request by signing a non-disclosure agreement.

**Are there any factors that restrict or prevent the sharing of (some of) the data (e.g. as defined in an agreement with a 3rd party, legal restrictions)? Please explain in the comment section per dataset or data type where appropriate.**

- Yes, Other

The dataset: '*Plasmatron experimental data (previous test campaigns)*' may contain test data from commercial test campaigns between the VKI and third parties, not meant for dissemination. This data will be stripped of its identifying information before integration into the processed database, storage and sharing.

**Where will the data be made available? If already known, please provide a repository per dataset or data type.**

The KU Leuven RDR will be used for all datasets except the proprietary VKI codes: '*LHTS methodology data processing code*' & '*Plasmatron data readout code*', which will be stored on the VKI Github server.

**When will the data be made available?**

The datasets will be made available as soon as possible after the end of the project. There is no reason to postpone sharing access.

**Which data usage licenses are you going to provide? If none, please explain why.**

The CC-BY-NC-ND-4.0 licence will be used for all datasets except the codes: '*LHTS methodology data processing code*' & '*Plasmatron data readout code*'.

**Do you intend to add a PID/DOI/accession number to your dataset(s)? If already available, you have the option to provide it in the comment section.**

- Yes

The data which is made available on the KU Leuven RDR, will receive a DOI.

**What are the expected costs for data sharing? How will these costs be covered?**

The datasets are expected to be small enough such that preservation in the KU Leuven RDR is free. Costs for maintaining the VKI Github server are covered by the VKI.

## 6. Responsibilities

**Who will manage data documentation and metadata during the research project?**

Roemer Spreij

**Who will manage data storage and backup during the research project?**

Roemer Spreij

**Who will manage data preservation and sharing?**

Olivier Chazot - at VKI. Valentijn De Smedt - at KU Leuven.

**Who will update and implement this DMP?**

Roemer Spreij