Development Status and Future of the European Electric Propulsion Plume Database

A.Reissner[1] and S.Hummel[2]
FOTEC Forschungs- und Technologietransfer GmbH, Wr. Neustadt, Austria

and

E. Gengembre[3]
ESA-ESTEC, Noordwijk, The Netherlands

Abstract: Within the scope of the project 'Assessment of the Interactions between Spacecraft and Electric Propulsion Systems' (AISEPS) a database has been developed comprising the digitalization of all openly available plume data of European electric propulsion systems from the early sixties up to today. The data includes experimental and theoretical results from ground testing, in-flight measurements and numerical simulations. The database has now been evolved to an online platform with the intention to provide a valuable tool for the electric propulsion community. The status of the database and the functionality of the online platform are being presented, and the future use of this tool is being discussed.

I. Introduction

Over the last 50 years a large amount of data with regard to Electric Propulsion systems and plume data was generated and it is difficult to have a good overview over this data pool due to its size and spread in time. In 2010, an extensive literature study has been performed in the scope of the ESA project AISEPS (Assessment of the Interactions between Spacecraft and Electric Propulsion Systems)[12], and all data found from

- Ground measurements (beam characterizations)
- Plume Simulations and
- In-Flight Plume characterizations

has been digitalized.

Furthermore, FOTEC has developed a database in order to easily find and compare this large amount of data. The database was intended to be used internally within the project to compare the new simulation capabilities for electric propulsion within SPIS-GEO against available data.

The database proved to be an extremely helpful tool and it was thus decided to undergo the effort of finding a way to provide this feature to the electric propulsion community.

This paper gives an overview of the data that is included in the database so far and the currently ongoing evolution of the software into an online platform that should be accessible to the community around the coming year change.

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[1] Head of Department, Aerospace Engineering, reissner@fotec.at
[2] Research Scientist, Aerospace Engineering
[3] Technical Officer, Electric Propulsion Section (TEC-MPE)

II. The European EP Plume Database

A. Content of Digitalized Data

The European Electric Propulsion Plume Database currently includes results from ground measurements, flight data and simulations about the plume characteristics of 11 major European electric propulsion systems.

- Hall Thrusters — SPT-100, PPS 1350 and PPS 5000 by SNECMA
- Radiofrequency Ion Thrusters — RIT 10 and RIT 22 by ASTRIUM
- High Efficiency Multistage Plasma Thrusters — HEMP 3050 by THALES
- Kaufman Configuration Ion Thrusters — T5 and T6 by QUINETIQ
- Field Emission Electric Propulsion Thrusters — Cs-FEEP by ALTA and In-FEEP by FOTEC

En extensive literature study has been performed in 2010 and data from more than 100 papers and proceedings has been digitalized.

The number of digitalized results per thruster is shown in Figure 1, summing up to 687 digitalized curves. More than two thirds of those (470) are results from ground testing and 214 from simulations. The only in-flight plume characterization included in the database today is from SPT100 on the Russian Express Satellites[3].

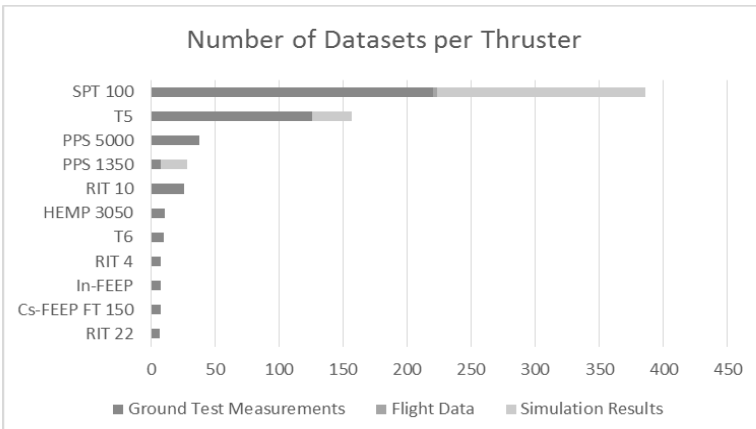


Figure 1 Number of digitalized results (=Datasets) per thruster

Figure 2 shows the variety of data included in the database by depicting the number of digitalized measurements of different kinds of probes. This variety makes it necessary to generate a data structure that is inherently flexible with respect to different kinds of data.

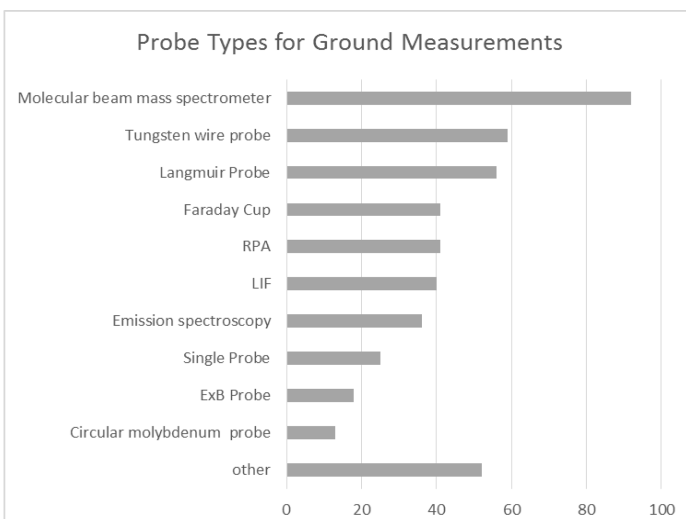
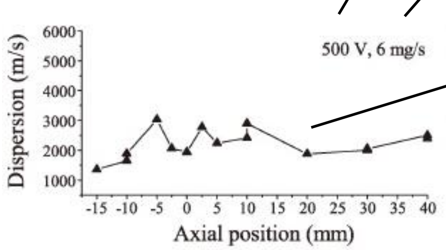


Figure 2 number of ground measurement results using various kinds of probes

B. Data Structure

The digitalized results are organized in the database as individual data sets. A Data Set represents one single measurements or simulation of any given parameter (y-Axis) varied over another parameter (x-Axis). This allows to include a large number of different measurements in the same database structure. Figure 3 shows an example on how data is digitalized in the database. Each Data Set consists of a general part including a number of information about the test or simulation and the digitalized x-y data where the parameters defining each axis can be specified freely.



General Information	
Thruster	PPS 5000
Discharge Voltage	500
Type of Data	Ground
Probe Type	LIF
Probe Cross Section	Fraction
Background Pressure	0,0014
Anode Mass Flow Rate	6
Cathode Mass Flow Rate	0,600000024
…	
…	
x-y Data	
Axial Distance (m)	**Velocity dispersion (m/s)**
0	1952,38
0,00236686	2761,9
0,00497041	2238,1
0,0101775	2952,38
0,0101775	2380,95
0,0198817	1904,76
0,0300592	2047,62
0,0402367	2428,57
…	…

Figure 3 Digitalization of literature data[4] into a Data Set

In general, a dataset includes <u>all</u> of the following information:

- Thruster
- Literature Reference
- Type of Data (Ground measurement, Flight data, Model/Simulation)
- Specification of the x- and y-Axis of the data (for example x: Angle, y: Ion Energy Distribution)
- Measurement data contained in a data file (two columns: x,y)
- Probe type for measurements or 'no probe' for simulation data (see Figure 2)
- Zone in the Environment Map (Plume, Backflow)
- The two performance parameter defining the performance map of the Thruster (for example for SPT 100 this is Discharge Voltage and Anode Mass Flow Rate). Those parameters always have to be defined in order to associate the measurement with the performance map.

In addition to these mandatory parameters, each dataset includes as many of the following information as could be found.

- Performance parameter
  - Thrust, ISP, Discharge Voltage, Beam Voltage, Accelerator Voltage, Discharge Current, Power, Mass Efficiency, Anode Mass Flow Rate, Cathode Mass Flow Rate
- Geometric parameter of the measurement
  - Minimal and maximal angle from plume axes **or** distance from plume axes, Distance to the exit plane
- Test Parameter for ground testing
  - Test Facility
  - Background pressure in the vacuum chamber
  - Species present in the vacuum chamber
- The original graph from the literature
- Additional comments or descriptions of the measurement/simulation

The datasets inherit some information from more general tables. This is show in Figure 4. This means that if for example a new thruster is to be included in the database, the information about the thruster (nominal performance, performance map, general information etc.) has to be specified in the database once. Then each dataset referring to this thruster automatically inherits all this information. The same is true for fest facilities, types of probes and literature references, but also for the x- and y-axes representing available measurement parameters

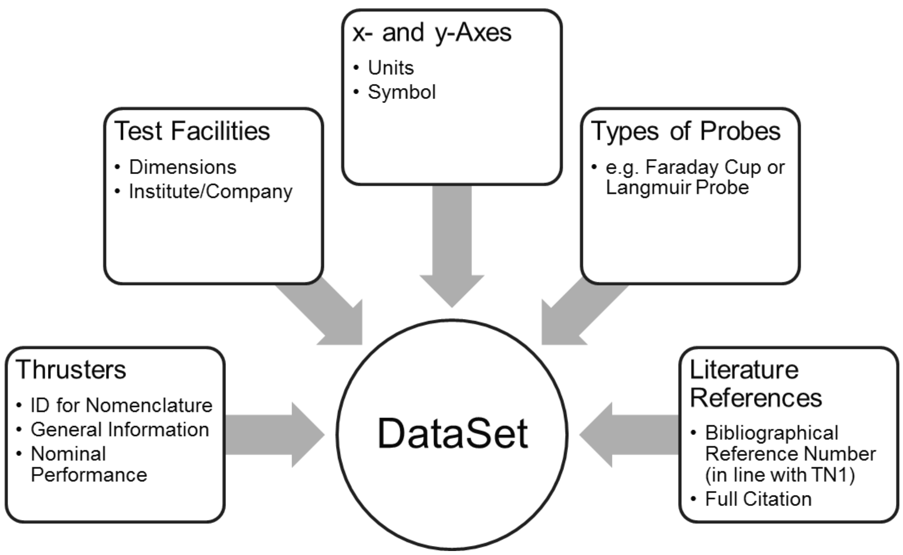


Figure 4 Information inherited by the datasets

Each dataset has a unique name that is assigned automatically when new information is entered into the database. It consists of a first part acting as an identifier and a second part for information only. The naming scheme (shown in Figure 5) has been chosen in order to provide a compromise between short names and easy readability.

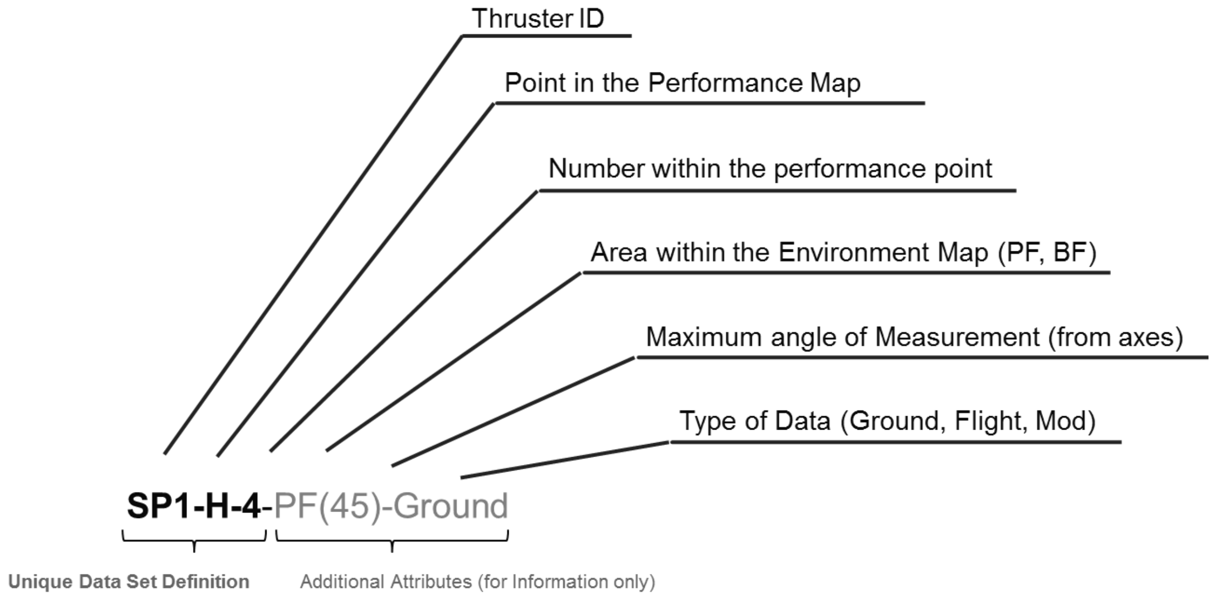


Figure 5 Naming scheme of the data sets

C. Front-End Capabilities

The main goal of the development of the original database was to make the large amount of digitalized data available in a user-friendly way. This also included a focus on the implementation of various methods to export data as customizable as possible.

Depending on the status of the user, he or she can for exmple:

- Search the database for measurements
  When looking for data, the user is guided through a selection process where he/she can find for example all data on the ion energy distribution for a SPT 100 plume.
- Visualize the measurements in a user defined graph.
  The graph can be exported to the clipboard (e.g. to include it in a Word file)
- Export the data in a user defined export file
  csv, txt, dat files can be written with a customizable delimiter and measurement separation by blank lines can be included
- Add a new thruster to the database or change a thruster in the database (e.g. the newly added thruster)
- Add new measurements to the database
  Data files can be imported (supporting different file formats).
- Change /add new resources to the database (e.g. Literature references, data axes, tests facilities,...)
- Change data already in the database.

III. Evolution of the Database

Since the database proved to be an extremely valuable tool during the AISEPS activity, ESA suggested to investigate the possibility to provide the functionalities to the electric propulsion community. In order to do so, two issues had to be addressed. First, the software had to be evolved with respect to a practicable frontend distribution and data management and second, the possibility to include the collected and digitalized data in the tool had to be investigated. In the following, the found solutions to these two issues are being described in more detail.

D. Software and Data Distribution

The European EPT Plume Database in its current version is a stand-alone software, thus the only way to distribute it within the electric propulsion community is to make the software accessible on a download-site. The user can then download and install the software locally with all data sets being stored on his computer, as shown in Figure 6.

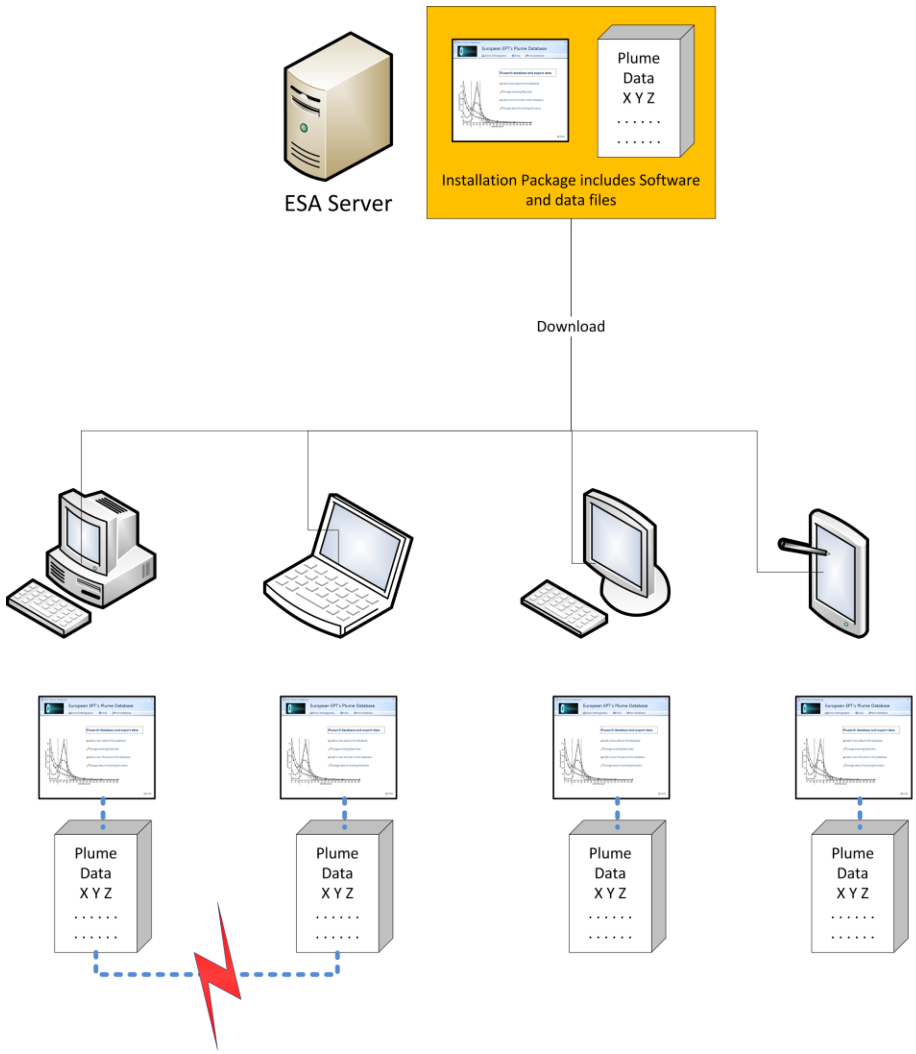


Figure 6 Database distribution: Locally installed frontend using local data (current version)

This procedure makes it almost impossible to update the database beyond its current state. If the functionality to add data to the database is being used by someone who has downloaded the database, for example a member of the community who wants to share the latest measurements of his thruster development, the added data is stored only locally at his workstation and not accessible by other users. There is no exchange of data between the users, which is indicated by the red flash in Figure 6. If on the other hand ESA wants to add new data to the database, each user would have to download and install the latest version of the database before being able to access the latest data.

In order to make use of the full functionality of the database within a group of users, two possible evolutions of the database can be identified.

1. Migration of all plume data to a database stored on an ESA server and update of the frontend to access this shared database. This allows for the exchange of data within the community, and will enable the database to grow with new data being added.
2. Programming of a new web-interface (with the same functionality as the current software). This will omit the necessity to install a client software to access the database and thus allow the database to be easily used independently of the operating system of the user.

In the following the two options are being discussed.

1. Installable frontend using a common database

The migration of the plume data to an ESA server is shown in Figure 7. In this scenario, a software is downloaded and installed by the user, not containing any plume data. The user then connects to the ESA server with a username and password and can access the complete set of plume data. On the ESA server, a user management can be implemented to restrict the functionality of the database for certain user groups. For example there might be a 'public' or 'guest' user who is allowed to search for data and export them, but is not allowed to add new data to the database. This functionality could only be accessible when a user has registered and is approved by ESA.

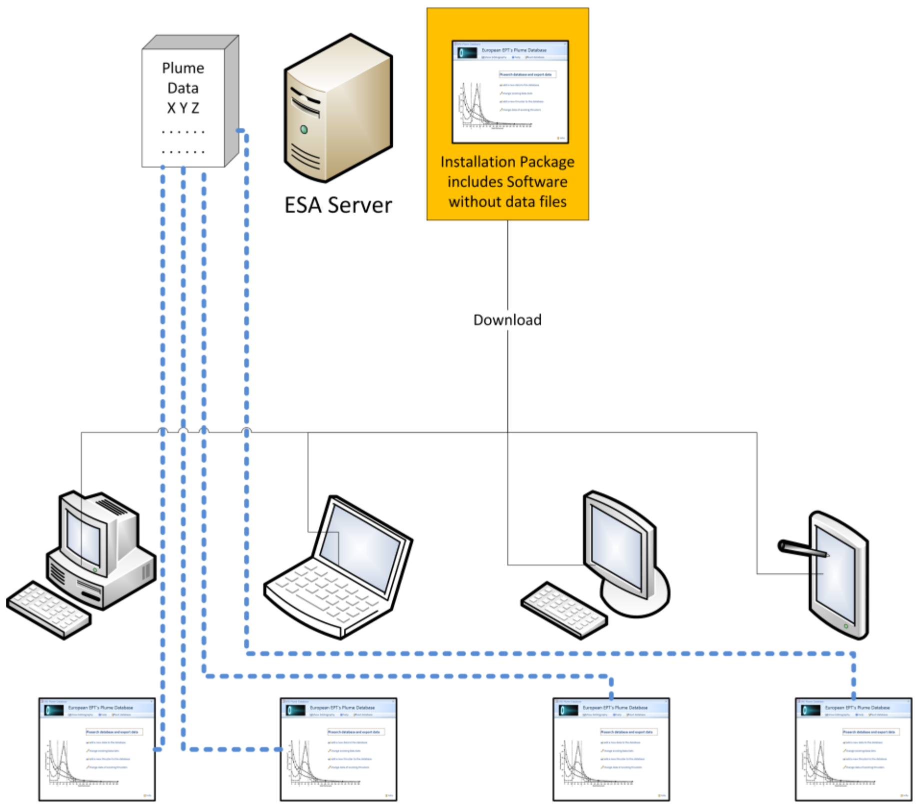


Figure 7 Database distribution: Locally installed frontend using a common database

The advantage of this upgrade is clearly the possibility to manage the data for all users, as well as the possibility to provide data from within the community.

The drawback of this solution is the fact that users still have to install a software package locally on their machine. Updates in the functionality of the software will therefore be difficult. Also, the software is not platform-independent and might not work on future releases of Windows, making the whole database obsolete or introducing an additional maintenance effort.

2. Online platform with web-interface

The drawbacks of a software installation can be overcome by migrating the database frontend to a web-interface, keeping all of its functionality. This solution is shown in Figure 8.

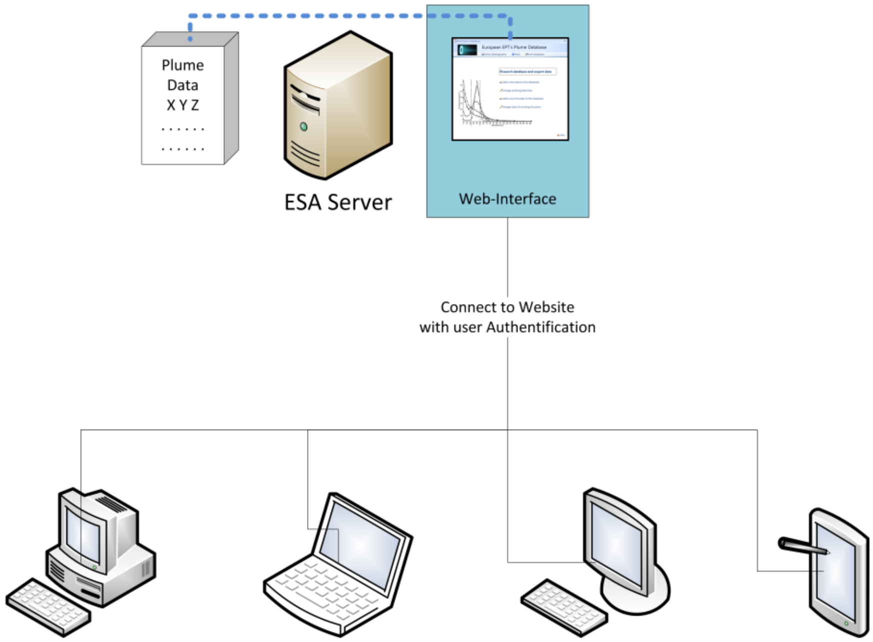


Figure 8 Database distribution: Online frontend using a common database. No installation required.

In this scenario, the user does not have to install any software, making the database truly platform-independent. He or she simply connects to a website and authenticates himself/herself with a username and password. Of course the distinction between guest users, users being trusted to add data and administrators can be made easily. In addition, one can implement a two-step implementation of new data to the database. The user will input data and personnel responsible for the database (as administrators) will be notified. This responsible person will then have to check the data and approve them to be included in the common database.

E. Use of already digitalized data in the online platform

The developed Online EP Plume Database has the potential of being a valuable tool, but by itself is only an empty platform, only providing functionalities that have shown to be valuable. In order to provide also the large amount of data that has been digitalized within the AISEPS project, the written consent of all cited authors has to be gathered. Efforts are currently ongoing to gather so called ‘data release forms’ signed by the authors of the digitalized papers.

IV. Conclusion and Outlook

Within the ESA activity AISEPS a database has been established by FOTEC with the intention to summarize all available results from ground measurements, flight data and simulations about the plume characteristics of all major European electric propulsion systems. The plume considered is the 4π solid angle plasma environment generated around the thruster, thus including the plume as well as back flows.

FOTEC and ESA agreed that the extensive efforts made to collect and digitalize an incredibly large amount of data, as well as to develop and improve functionalities to manage such data, should be honored by making the database accessible to the electric propulsion community worldwide. Also, considerations have been made on how to evolve the current version of the database into a living tool that can be used by the community in the future.

The most reasonable solution seems to be the implementation of an online interface, which is currently being developed by FOTEC and is planned to go online by the beginning of 2014.

On the new platform, users will be able to

- Register at the database web-page (address to be announced)
- Search for data, visualize it and export (download)
- Upload their own results to make them accessible by the community

It is clear that the value of the database in the future will highly depend on the participation of the EP community by providing information not yet contained in the data base, checking the included information with regard to accuracy and being up-to-date and providing feed-back with regard to usefulness and potential for improvement.
With this active participation, the EP Plume database has the potential to become a valuable and living tool supporting all members of the EP community with a good overview of up to date plume data for any electric propulsion system available.

References

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