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1. **Nature:** R = Report, P = Prototype, D = Demonstrator, O = Other
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Public	Restricted to other programme participants (including the Commission Service)	Restricted to a group specified by the consortium (including the Commission Services)	Confidential, only for members of the consortium (excluding the Commission Services)

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Executive Summary/Abstract: We report the developments and services made operational during the third year of the Sun Planetary Interactions Digital Environment on Request (SPIDER) Virtual Activity of the Europlanet 2024 Research Infrastructure. During the third year of the project, all six foreseen services are now operational with five of them being improved or extended.

Deliverable

1. Explanation of work & Overview of progress

1.1 Objectives

The H2020 Europlanet 2020 Research Infrastructure (RI) programme, which ended on Aug 31st, 2019, included an activity called Planetary Space Weather Services (PSWS), which provided 12 services distributed over four different domains (A. Prediction, B. Detection, C. Modelling, D. Alerts) and accessed through the PSWS portal (http://spider-europlanet.irap.omp.eu/#europlanet):

A1. 1D MHD Solar Wind Prediction Tool – HELIOPROPA,

A2. Propagation Tool,

A3. Meteor showers,

A4. Cometary tail crossings – TAILCATCHER,

B1. Lunar impacts – ALFIE,

B2. Giant planet fireballs – DeTeCt3.1,

B3. Cometary tails – WINDSOCKS,

C1. Earth, Mars, Venus, Jupiter coupling- TRANSPLANET,

C2. Mars radiation environment – RADMAREE,

C3. Giant planet magnetodiscs – MAGNETODISC,

C4. Jupiter's thermosphere,

D. Alerts.

In the framework of the Europlanet 2024 RI (EPN 2024 RI) programme, the Virtual Activity (VA) SPIDER (Sun-Planet Interactions Digital Environment on Request) will extend PSWS domain (A. Prediction, C. Modelling, E. Databases) services and give European planetary scientists, space agencies and industries access to six unique, publicly available and sophisticated services in order to model planetary environments and solar wind interactions through the deployment of a dedicated run on request infrastructure and associated databases.

C5. A service for runs on request of models of Jupiter's moon exospheres as well as the exosphere of Mercury.

C6. A service to connect the open-source Spacecraft-Plasma Interaction Software (SPIS) software with models of space environments in order to compute the effect of spacecraft potential on the scientific performances of charged particle instruments onboard space missions. Pre-configured simulations will be made for Bepi-Colombo and JUICE (JUpiter ICy moon Explorer) missions.

C7. A service for runs on request of particle tracing models in planetary magnetospheres.

E1. A database of the high-energy particle flux proxy at Mars, Venus and comet 67P using background counts observed in the data obtained by the plasma instruments onboard Mars Express (operational from 2003), Venus Express (2006–2014), and Rosetta (2014–2015).

E2. A simulation database for Mercury and Jupiter's moons magnetospheres and link them with prediction of the solar wind parameters from PSWS.

A1. An extension of the PSWS Heliopropa service in order to ingest new observations from Solar missions like the ESA Solar Orbiter or NASA Solar Parker Probe missions and use them as input parameters for solar wind prediction.

The annual report of SPIDER at the end of the third year of the project is described below.

1.2 Explanation of the work carried per WP

SPIDER consists of 4 Tasks and the work performed during the third year of the project for each of them is detailed below:

Task 1. Coordination **(Lead: CNRS, Deputy: WIGNER).**

Task 1 coordinates and manages the overall WP. CNRS reports the status of SPIDER developments and services during monthly telecons with the EPN 2024 RI Project Management Committee (PMC). Since each of the foreseen SPIDER services to be developed are independent, CNRS is directly interacting with each of the responsible institutes by email or telecons. This was still the case during the third year of the project.

Task 2. Implementation of new space weather services **(Lead: CNRS, Deputy: INAF, Participants: IRF, ONERA, UCL).**

All six SPIDER services are operational at http://spider-europlanet.irap.omp.eu/. Work is ongoing in the third and fourth years to improve and extend five of these services C5, C7, E1, E2, and A1.

The C5 service is operational and available through a HTPPD interface (Apache 2) that can be reached at http://150.146.134.250 (go to "model" http://150.146.134.250/cgi-bin/modello-input.pl?template=si and then to "full model" http://150.146.134.250/cgi-bin/modello-input.pl?psd=si&td=si&pgr=si&qgr=si&igr=si&info=si&sw=si&map=si&exo=si&term=si&ref=no). An extension to Ganymede is being considered by INAF.

The C7 service is operational (see Guio et al., Trapped Particle Motion in Magnetodisk Fields, Journal of Geophysical Research: Space Physics, Volume 125, Issue 7, article id. e27827, doi: 10.1029/2020JA027827, 2020 for reference). A MATLAB framework to create the executable is publicly available at http://spider-europlanet.irap.omp.eu/modelling and is being made operational by CNRS/IRAP through its run-on-request architecture in a similar way as the C3 MAGNETODISC service developed during PSWS.

The E1 service is operational and available in the Automated Multi-Dataset Analysis (AMDA) tool developed by CNRS http://amda.cdpp.eu. The Mars Express database is extended when the new data from the mission that is still in operation are analysed. Extension to Rosetta ICA is being considered.

Simulations of Mercury's magnetosphere for the E2 service are available in the Automated Multi-Dataset Analysis (AMDA) tool developed by CNRS http://amda.cdpp.eu, and work is ongoing to extend the database when the submitted publications will be accepted.

The A1 service for predictions of the solar wind parameters propagated to BepiColombo, Solar Orbiter and Parker Solar Probe is operational and available through the Heliopropa service http://heliopropa.cdpp.eu and the Automated Multi-Dataset Analysis (AMDA) tool developed by CNRS http://amda.cdpp.eu. It is currently being extended to use Solar Orbiter data as inputs for predictions to planets, spacecraft, and comets.

Task 3. Deployment of consolidated runs on request architecture **(OBSPARIS, CNRS).**

This has, so far, been driven by VESPA needs but will be adapted and applied in year four to SPIDER services. The implementation of an OPUS server at CNRS/IRAP, for managing the jobs of the hosted modelling codes, begun in January 2022. It will rely on the development done at OBSPARIS (https://github.com/ParisAstronomicalDataCentre/OPUS) and be applied to PSWS services too (Transplanet, Magnetodisc). The use of the eduTEAMS-hosted Europlanet VESPA AAI (Authorization and Authentication Infrastructure), provided by GÉANT, to manage the user access authorizations as well as the implementation of OPUS on EOSC facilities remains to be studied in a later stage in coordination with the ESCAPE H2020 project.

Task 4. Dissemination and Liaisons **(WIGNER RCP, CNRS)**

CNRS has developed and maintained a website to promote SPIDER activities, available at https://spider-europlanet.irap.omp.eu/about. CNRS regularly presents SPIDER developments to the BepiColombo, Juno, JUICE, and Solar Orbiter communities. CNRS and WIGNER RCP

proposed and organized a session devoted to Planetary Space Weather during the EPSC conference in September 2022.

MITM6 Planetary space weather

The emphasis of the session is on all aspects of the conditions in the Sun, solar wind and magnetospheric plasmas that extend the concepts of space weather and space situational awareness to other planets in our Solar System than Earth, and in particular to spacecraft that travel through it. Abstracts on space- and ground-based data analysis, theoretical modeling and simulations of planetary space weather are welcomed. The description of new services accessible to the research community, space agencies, and industrial partners planning for space missions and addressing the effects of the environment on components and systems are also strongly encouraged. This session will also summarize the planetary space weather services developed during Europlanet 2024 RI with the Sun Planetary Interactions Digital Environment Run on request.

https://meetingorganizer.copernicus.org/EPSC2022/session/44610

It took place on Thursday, 21 Sep, 13:00–17:00 (orals) and 18:45-20:15 (posters).

There were 6 oral presentations during the session which was attended by 38-45 persons, and 3 posters.

1.3 Impact

In practice, several actions have been conducted during the third year:

Continuous involvement, promotion and use of services for current (Juno) or future planetary missions (BepiColombo, JUICE) as well as heliophysics missions (Solar Orbiter)

- Juno/Giant Planet Systems Exploration, 30 mai-01 juin 2022, 01 May 2022, Château de Mons-en-Armagnac, France
- BepiColombo Science Working Team, 21-24 November 2022, Kobe, Japan
- JUICE Science Working Team, Radiation splinter, 08 December 2022, IRAP, Toulouse, France

- Use of SPIDER E1 and C5 services for Mars Express and for Juno. Several publications resulted from the use of these services in 2022:

    1. Futaana, Y., et al., Galactic Cosmic Rays at Mars and Venus: Temporal Variations from Hours to Decades Measured as the Background Signal of Onboard Microchannel Plates, The Astrophysical Journal, Volume 940, Issue 2, id.178, 12 pp., doi:10.3847/1538-4357/ac9a49
    2. Moroni, M. et al., Micro-meteoroids impact vaporization as source for Ca and CaO exosphere along Mercury's orbit, Submitted to Icarus, 2022

    One press release was done by Europlanet in the issue 4 of the Europlanet magazine:

    https://www.europlanet-society.org/europlanet-magazine/issue-4/hidden-in-the-noise/

- Dedicated SPIDER proposed and session on space weather organised at the EPSC 2022 conference

- A SPIDER session and a SPIDER booth will be proposed for the next ESWW (European Space Weather Week) conference in Toulouse, November 2023

- Use of SPIDER E2 and A1 services for the BepiColombo Venus flyby in October 2020, August 2021, and for the first Mercury flyby in October 2021. Several publications resulted from the use of these services in 2022:

    1. Persson, A., S. Aizawa, N. André, S. Barabash, S. Saito, Y. Harada, S. Heyner, S. Orsini, A. Fedorov, C. Mazelle, Y. Futaana, L. Z. Hadid, M. Volwerk, G. Collinson, B. Sanchez-Cano, A. Barthe, E. Penou, S. Yokota, V. Genot, J. A. Sauvaud, D. Delcourt, M. Fraenz, R. Modolo, A. Milillo, H.-U. Auster, I. Richter, J. Z. D. Mieth, P. Louarn, C. J. Owen. T. S. Horbury, K. Asamura, S. Matsuda, H. Nilsson, M. Wieser, T. Alberti, A. Varsani, V. Mangano, A. Mura, L. Gunter, G. Laky, H. Jeszenszky, K. Masunaga, C. Signoles, M. Rojo, and G. Murakami, Persson, M., Aizawa, S., André, N. et al. BepiColombo mission confirms stagnation region of Venus and reveals its large extent. Nature Communications 13, 7743 (2022). https://doi.org/10.1038/s41467-022-35061-3

    2. Harada, Y., S. Aizawa, Y. Saito, N. André, et al., BepiColombo Mio Observations of Low-Energy Ions During the First Mercury Flyby: Initial Results, Geophysical Research Letters, Volume 49, Issue 17, article id. e00279, doi:10.1029/2022GL100279

    3. Aizawa, S., M. Persson, T. Menez, N. André et al., LatHyS global hybrid simulation of the BepiColombo second Venus flyby, Planetary and Space Sciences, 218, doi: 10.1016/j.pss.2022.105499, 2022

    4. Aizawa, S., A.L.E. Werner, N. André, R. Modolo, S. A. Boardsen, F. Leblanc, V. Genot, J. M. Raines, F. Lavorenti, P. Henri, and F. Califano, Influence of IMF rotation in the solar wind on the response of Mercury's magnetosphere: revisiting Mariner 10 observations, Planetary Space Science, in revision, 2022

    5. Hadid, L. Z., D. Delcourt, Y. Saito, M. Franz, S. Yokota, B. Fiethe, C, Verdeil, B Katra, F. Leblanc, H. Fischer, M. Persson, S. Aizawa, N. André, A. Fedorov, D. Fontaine, N. Krupp, H. Michalik, J-M. Illiano, J-J. Berthelier, H. Kruger, Y. Harada, G. Murakami, and S. Matsuda, BepiColombo observations of escaping carbon and oxygen ions in Venus magnetosheath, Nature Astronomy, in revision, 2022

    6. Aizawa, S., Y. Harada, N. André, Y. Saito, et al., Direct evidence of substorm-related impulsive injections of electrons at Mercury, Nature Communications, submitted 2022

One press release is in preparation by Europlanet for Persson et al., Nature Communications, 2022

1.4 Access provisions to Research Infrastructures

Statistics for the SPIDER portal (website) that has been developed since the first year of the project can be found on http://spider-europlanet.irap.omp.eu/about (**6678 since 01/02/2020**)

Statistics for the SPIDER services E1 and A1 can be found at the following webpages:

- AMDA tool (total number of connections of different users, https://admda.cdpp.eu/):

https://amda.cdpp.eu/awstats/awstats.pl more than 17017 connections since 01/02/2020

- Details on geographical distribution etc. can be found at CDPP/AMDA awstats: https://amda.cdpp.eu/awstats/awstats.pl

https://heliopropa.cdpp.euhas received 14335 visits since 2017.

2. Update of exploitation & dissemination plan

No change since the start of the project.

3. Update of data management plan

The Europlanet 2024 RI data management plan can be found in full in deliverable D1.3.

4. Follow-up of recommendations & comments from previous review(s)

The report from the VA external review board (deliverable D1.8) was received at the end of July 2022.
The following actions have been performed to follow these recommendations:

- Maintenance of the PSWS portal ongoing (replace future tense by past tense)

5. Deviations from Annex 1 (DoA)

5.1 Tasks

N/A

5.2 Use of resources

Patrick Guio (now at University of Tromso with a more permanent position) left UCL during the course of the project but has been employed part-time by UCL (0.2 FTE) to undertake previously agreed Europlanet 2024 RI work.

- **5.2.1 Unforeseen subcontracting**
  N/A
- **5.2.2 Unforeseen use of in-kind contributions from a 3rd party against payment or free of charge**
- N/A