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Deliverable D5.4

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Co-ordinator:	Prof Nigel Mason

1. **Nature:** R = Report, P = Prototype, D = Demonstrator, O = Other
2. **Dissemination level:**

PU	PP	RE	CO
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)

Executive Summary / Abstract: We report the developments and services made operational during the second year of the Sun Planetary Interactions Digital Environment on Request (SPIDER) Virtual Activity of the Europlanet 2024 Research Infrastructure. During the second year of the project, four of the six foreseen services have started as planned their developments, with two of them prototyped and three others already operational.

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1. Explanation of WP5 work & Overview of progress

a. Objectives

Objective 5: to expand Europlanet's unique planetary space weather service (SPIDER), to provide predictions and alerts for spacecraft operations and science data analysis.

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 starting 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 BepiColombo 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, linking them with predictions 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 second year of the project is described below.

b. Explanation of the work carried per WP

SPIDER consists of 4 tasks and the work performed during the second 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 all 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 the case during the second year of the project with ONERA and UCL.

Task 2. Implementation of new space weather services **(Lead: CNRS, Deputy: INAF, Participants: IRF, ONERA, UCL).**
The two services being developed during the second year of the project are C6 (Lead: ONERA) and C7 (Lead: UCL). http://spider-europlanet.irap.omp.eu/modelling

The first service has been prototyped and is fully available at https://w3.onera.fr/spacecraft_charging/fr/europlanet.

The development of the C7 service is ongoing (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 has been prototyped and will be transmitted to CNRS in order to make it operational through its run-on-request architecture in a similar way as the C3 MAGNETODISC service developed during PSWS.

The C5 service is still 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).

The E1 service is still operational and available in the Automated Multi-Dataset Analysis (AMDA) tool developed by CNRS (http://amda.cdpp.eu).

The development of the E2 service for simulations of Mercury's magnetosphere is ongoing and will be available in the AMDA tool (http://amda.cdpp.eu) at the end of the third year.

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 AMDA tool (http://amda.cdpp.eu). It will be extended at the end of the third year 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 the third and fourth years to SPIDER services. A run-on-request prototype has been implemented at OBSPARIS, using the OPUS framework (https://github.com/ParisAstronomicalDataCentre/OPUS). It is currently used for running the ExPRES code (https://voparis-uws-maser.obspm.fr/client/). The current plans are twofold: (i) implement an OPUS server at CNRS/IRAP, for managing the jobs of the hosted modelling codes; (ii) use the eduTEAMS-hosted Europlanet VESPA AAI (Authorization and Authentication Infrastructure), provided by GÉANT, to manage the user access authorizations. In a later stage, the implementation of OPUS on EOSC facilities will be studied, in coordination with the ESCAPE H2020 project.

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

CNRS has developed a website to promote SPIDER activities, available at http://spider-europlanet.irap.omp.eu/about. CNRS regularly presents SPIDER developments to the BepiColombo and Solar Orbiter communities, in particular the C5, E2, and A1 services. CNRS and WIGNER RCP proposed a session devoted to

Planetary Space Weather during the virtual EPSC conference in September 2021. It was merged with another session in order to maximize the number of participants and took place on Monday, 20 September, 10:40–11:25.

The abstract of the **TP8 Planetary space weather and space weathering on airless bodies** was the following:

The surfaces of airless celestial bodies are directly exposed to environmental radiation, ions, and micrometeoroids. The result of these interactions is an alteration of the surface structure and chemical composition, generally referred to as space weathering. At the same time, these interactions release surface material that refills the surface-bounded exosphere and, directly or indirectly, is a source of planetary ions in the environment. The study of the planetary response to variable external conditions is the broad meaning of planetary space weather.
Over the next decade, the BepiColombo mission to Mercury and JUICE mission to Jupiter's system, together with the Moon space exploration program, will offer unprecedented opportunities to investigate the interaction processes at airless bodies.
In the present session, we welcome observation-driven, theoretical, and experimental studies
• on all the airless bodies interacting with solar wind (like Mercury, Moon and asteroids) or with magnetospheric ions (outer planets icy moons);
• on micrometeoroid gardening and impact vaporization effects onto the surface and onto the exosphere;
• on the effects of other agents like photons, electrons, and high-energy particles;
• on laboratory experiments for investigating surface release processes and surface modifications.
• on spectral measurements of various planetary analogues undergoing space weathering processes.

Share: https://meetingorganizer.copernicus.org/EPSC2021/session/41621
The conveners of the session were Anna Milillo (INAF), Sae Aizawa IRAP), André Galli (Univ. Bern), Indhu Varatharajan (DLR).

There were 12 oral and poster presentations submitted to the session:

https://meetingorganizer.copernicus.org/EPSC2021/session/41621#Oral_and_Poster_presentations_and_abstracts

SPIDER objectives were introduced by Nicolas André (CNRS) during the session, and a science case with the C5 service detailed by Martina Moroni (INAF).

c. Impact

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

- Continuous involvement, promotion and use of services for current or future planetary missions (BepiColombo, JUICE) as well as heliophysics missions (Solar Orbiter); e.g. a report about synergistic observations with BepiColombo, Solar

Orbiter, Parker Solar Probe in the heliosphere in order to track propagation of solar wind disturbances has been published, making use of Heliopropa and the AMDA tool (Hadid, L. Z., V. Genot, S. Aizawa, A. Milillo, J. Zender, G. Murakami, J. Benkhoff, I. Zouganelis, T. Alberti, N. Andre, Z. Bebesi, F. Califano, A. P. Dimmock, M. Dosa, C. P. Escoubet, L. Griton, G. C. Ho, T. S. Horbury, K. Iwai, M. Janvier, E. Kilpua, B. Lavraud, A. Madar, Y. Miyoshi, D. Muller, R. F. Pinto, A. P. Rouillard, J. M. Raines, N. Raouafi, F. Sahraoui, B. Sanchez-Cano, D. Shiota, R. Vainio, and A. Walsh, BepiColombo's Cruise Phase: Unique Opportunity for Synergistic Observations, Front. Astron. Space Scie., doi: https://doi.org/10.3389/fspas.2021.718024, 2021).

- A dedicated SPIDER session was proposed and merged with a session on planetary space weather and space weathering of airless bodies organised at the virtual EPSC 2021 conference.

- Use of SPIDER services for the BepiColombo Venus flyby in October 2020, August 2021, and for the first Mercury flyby in October 2021, with use of SPIDER services E2 and A1. Publications resulting from the use of these services are being submitted in January 2022:

1. Persson, A., S. Aizawa, N. Andre, Y. Saito, S. Barabash, Y. Harada, A. Fedorov, C. Mazelle, Y. Futaana, V. Genot, L. Z. Hadid, G. Murakami, M. Volwerk, G. Collinson, B/ Sanchez-Cano, A. Barthe, E. Penou, M. Fraenz, D. Delcourt, S. Yokota, R. Modolo, D. Heyner, S. Orsini, A. Milillo, P. Louarn, C. Owen. T. Horbury, J.A. Sauvaud, K. Asamura, S. Matsuda, H. Nilsson, M. Wieser, T. Alberti, A. Varsani, L. Gunter, and E. Kallio, A subdivided Venusian magnetosheath resolved by multi-spacecraft observations, **Submitted to Science, 2021**

2. Aizawa, S., T. Menez, N. André, R. Modolo, M. Persson, A. Barthe, E. Penou, A. Fedorov, J.-A. Sauvaud, E. Werner, F. Leblanc, J-Y. Chaufray, Y. Saito, S. Yokota, G. Murakami, B. Sanchez-Cano, D. Heyner, T. Horbury, P. Louarn, C. Owens, LatHyS hybrid simulation of the August, 10 2021 BepiColombo Venus flyby, **Submitted to Planetary and Space Science, 2021b**

3. Aizawa, S., A.L.E. Werner, N. Andre, 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, **Submitted to Planetary Space Science, 2021a**

d. **Access provisions to Research Infrastructures**

Statistics for the SPIDER portal (website) as well as for the C5 service that has been developed during the first year of the project and statistics for the SPIDER services E1 and A1 can be found at the following webpages:

– AMDA tool (total number of connections, http://amda.cdpp.eu/):

http://amda.cdpp.eu/awstats/awstats.pl more than **11570 connections since 01/02/2020**

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

http://heliopropa.cdpp.eu has received 10994 visits since 2017.

2. Update of exploitation & dissemination plan

No change since the start of the project.

3. Update of data management plan

The Projects overall DMP can be found in Deliverable D1.3. An update of the DMP is due at the end of February 2022.

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

The report from the VA review board (Deliverable D1.5) was received mid-December 2020, and has been reviewed by the WP management team which has agreed to the following actions :

- The sustainability of PSWS services shall be revised
- The SPIDER website shall be updated and more detail included
- A link to the deliverables shall be added for each service
- A link to the AMDA tool shall be provided.
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The following actions have been performed to follow these recommendations:

A SPIDER website has been established, but it is unpopulated.	We have added more information and a page counter.
The SPIDER report states that the existing PSWS site "provided 12 services", but then lists only 11 services, of which only 5 appear to be operational on that site. That is a significant deficit that puts this project at a substantial disadvantage for success.	We have checked all PSWS links and made all of them operational again except one (lunar impact software ALFIE).
A user guessing his way through the site may eventually find a video of the EPSC 2020 presentation, but apart from that there is no information on the site itself about schedules or planned development, or any indication that it is in active development.	We have added information on when the various tools are planned to be made operational.
And while the new home page looks good in a full-sized browser window on a large screen, it does not adapt well to changes in window size.	Corrected.
While it is apparently true that several significant databases have been added to the AMDA database/tool, that tool does not appear to be related to either SPIDER or the prior PSWS in any way. No reference could be found to it by name or link on either the new web site or the legacy PSWS site. Neither is there any reference to either PSWS or SPIDER on the AMDA site.	We will add references to SPIDER directly in the AMDA data tree and in the Heliopropa service.
No mention is made in either the report or the website of the planned Dissemination tasks - specifically special journal issues and dedicated conference sessions.	We have added News and Dissemination on the website.

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 will be employed part-time by UCL (0.2 FTE) d to undertake previously agreed EPN-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