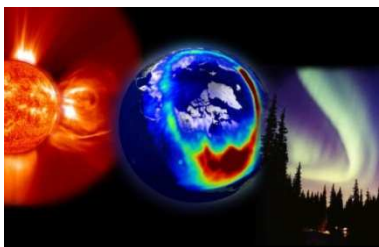
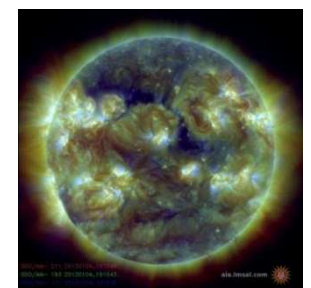


# Report on the “L5 in Tandem with L1: Future Space-Weather Missions Workshop” – Steps Toward a L5 Operational SWx Mission

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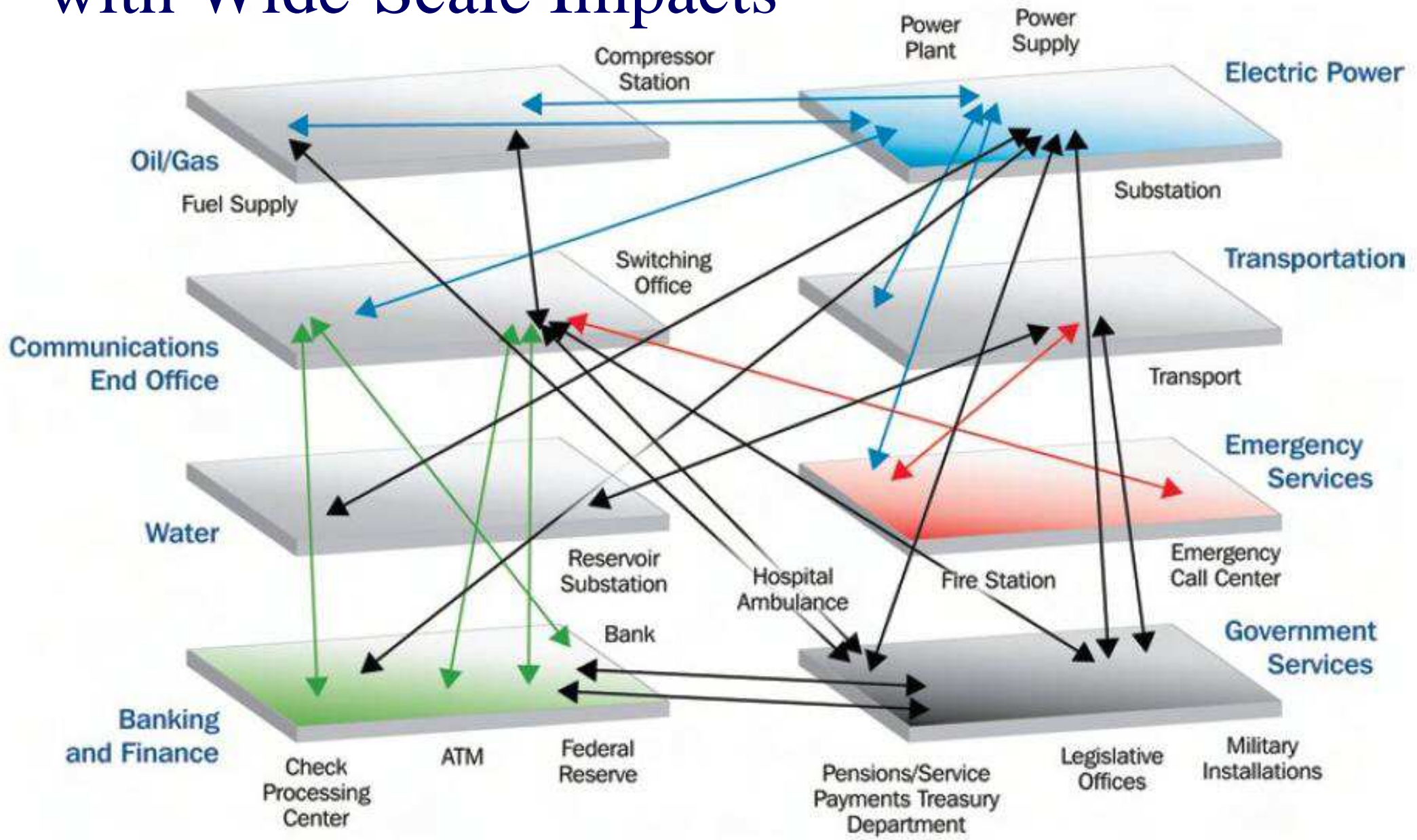


- Part 1: Why we want dedicated space-weather operations from  $L_5$  in tandem with  $L_1$ .
- Part 2: Outline of the “ $L_5$  in Tandem with  $L_1$ : Future Space-Weather Missions Workshop”.
  - Part 3: Key points from the workshop.
  - Part 4: Summary and where next?

Part 1:

**Why we want dedicated space-  
weather operations from L5 in  
tandem with L1.**

# Interconnected Systems with Wide-Scale Impacts



# Assessing the Risk

- UK's National Risk Register (NRR – 2015 edition) – other risks.
- Severe space weather has been on the UK's NRR since 2011.
- This, along with other additional risks, were brought to the government's attention following the problems caused by the Iceland volcano 'Eyjafjallajökull' ash clouds in 2010.
- Not just the UK government!
- UKSA funded a socio-economic study on space-weather impacts (IPSP) reporting to government.



# Current Capabilities

- State-of-the-art heliospheric capability is still not sufficient for space-weather forecasting for critical infrastructures.
- With the exception of the recently-launched DSCOVR spacecraft (11 February 2015) and the GOES geostationary satellites (~40-year programme), all space-weather observations and measurements, including the key model drivers, are from aging science instrumentation aboard science missions that are many years beyond their intended lifetimes.
- For continuity, it is essential that key near-Earth instrumentation be replaced ASAP (this seems to mean NOAA's SWFO at  $L_1$  following events of this week) and for enhanced forecasting capabilities, *i.e.* at least a second viewpoint/position is essential (off the Sun-Earth line –  $L_5$ )...

Part 2:

# **Outline of the “L5 in Tandem with L1: Future Space-Weather Missions Workshop”.**

# The Workshop (1)

- An interactive and active workshop from start to finish.
- L5 in Tandem with L1: Future Space-Weather Missions Workshop.
- Held at the Department for Business, Energy & Industrial Strategy (BEIS) conference centre in central London.
- Supported by the UK Government Office for Science (GO Science), Met Office, and STFC.
- Organised by STFC, Met Office, and NOAA SWPC.
- SOC Members from STFC, Met Office, NOAA SWPC, Predictive Science, Inc., and ESA.
- Website (agenda/abstracts/talks/photos/etc...): <https://goo.gl/X1BZxd> or <https://www.ukssdc.ac.uk/meetings/L5InTandemWithL1/>.
- Closing panel on the final day was broadcast live on social media and is also available at the website.





# The Workshop (2)



- Covered many key areas needed for L<sub>5</sub> and L<sub>1</sub> together:
  - Socio-Economic cases for space-weather mitigation;
  - International space-weather mission developments;
  - Forecaster requirements, compromises, and cross-agency issues;
  - Ground-based instrumentation/data in support of L<sub>5</sub>/L<sub>1</sub> missions;
  - Ground-segment requirements and considerations;
  - Modelling capability and gaps;
  - Instrumentation covering all aspects of remote-sensing and *in-situ* space-based capabilities/observations/measurements;
  - Mission options, payloads, priorities, and benefits; and
  - How L<sub>1</sub> and L<sub>5</sub> operational missions can complement each other and maximise the overall benefit to the international communities.

Part 3:

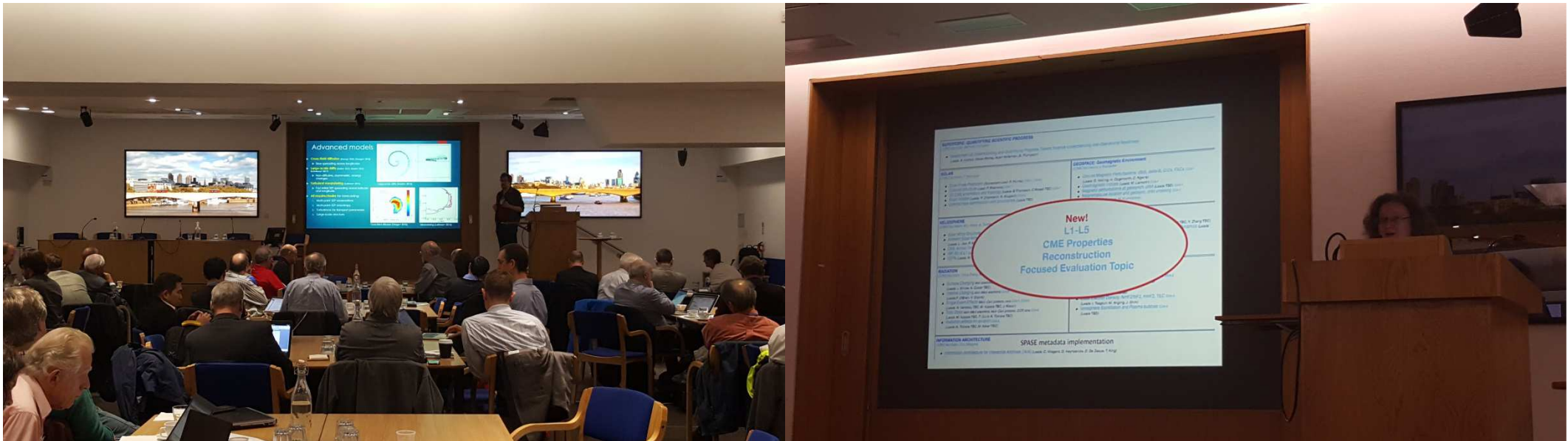
# **Key points from the workshop.**

# High-Level Key Points

- Opened by the BEIS Department Chief Scientific Advisor.
- Increasing convergence of views – both on L<sub>5</sub> rather than L<sub>4</sub> and also on the payloads that are really required (and their observational/measurement requirements and specifications).
- Still insufficient scientific evidence to support the full benefits for L<sub>5</sub>:
  - Much work still to be published which has been discussed and presented at meetings, but perhaps a formalisation of much of this work (*i.e.* peer-reviewed papers) is needed ASAP!
- Investment in Europe requires economic evidence for an L<sub>5</sub> mission, and current socio-economic studies are pointing in the right direction.
- Breadth of the participation (*i.e.* policy makers, government-related people, scientists, users, engineers, modellers, *etc...*) demonstrated the importance and need for an L<sub>5</sub> space-weather operational mission.

# Modelling Needs

- Huge enthusiasm from the modellers for working with both  $L_5$  and  $L_1$  data sources...
- CCMC/I-SWAT  $L_5$ - $L_1$  Challenge – preparing for future space-weather data and modelling capabilities...
  - This was a modelling outcome in general from modelling sessions.



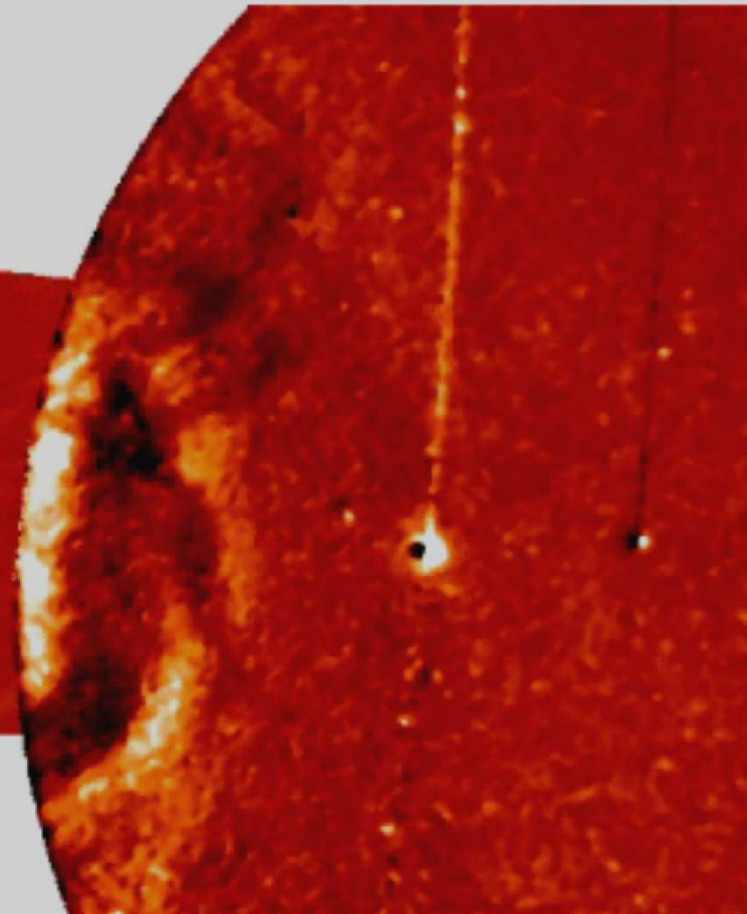
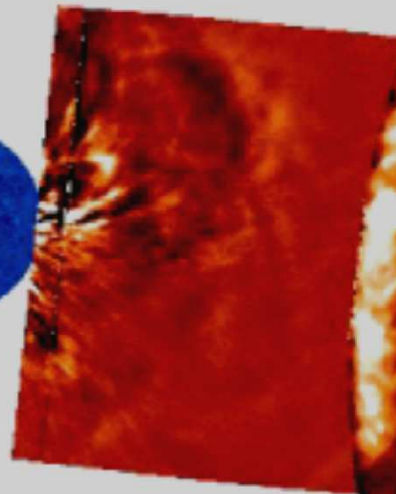
## Some Other Ideas Discussed...

- Magnetographs at both  $L_5$  and  $L_1$  – reduce calibration issues if both instruments are identical, and strong links to improved modelling.
- The importance in recognising that space-weather data also provide context for the human forecasters to make judgement calls that add value to the outputs of the various models that are used in forecasting.
- New instrumentation ideas and data downlink techniques that could form instruments of opportunity from other sources: EUV burst downlinks, polarising HIs, extra energy ranges from EP instruments...
- Real enthusiasm still for science from an operational mission – linking back to the previous  $L_5$  workshop in London in 2015 and also links to the science-based  $L_5$  Consortium Meeting in Göttingen, Germany, 17-20 October 2017: [https://cdaw.gsfc.nasa.gov/meetings/2017\\_L5C/](https://cdaw.gsfc.nasa.gov/meetings/2017_L5C/).
- Heliospheric imaging from  $L_5$ : full imaging of the Sun-Earth line...

# The Ability to Visually Track from Sun to Earth: White-Visible-Light Heliospheric Imaging

- Earth-directed CME – 06 March 2012 as imaged in Thomson-Scattered sunlight (courtesy J.A. Davies).

A “view” from L<sub>5</sub>...

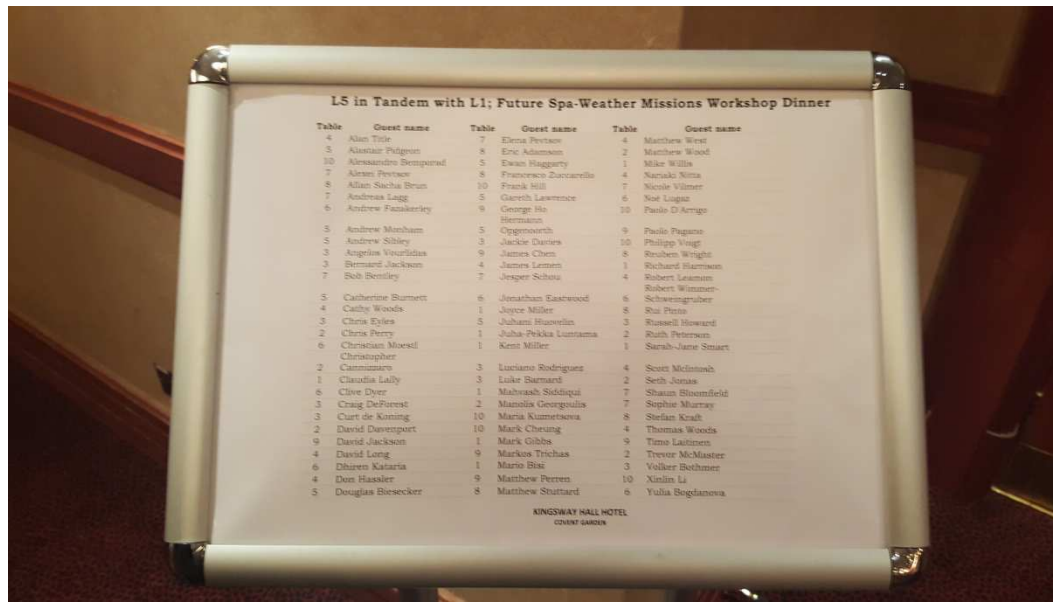




# Workshop ‘Wedding’ Dinner

## – Homework...(1)

- The workshop dinner was a working dinner – there was some surprise homework assigned; bit of the shock to some participants...
  - There was a challenge set for consolidating spacecraft instrumentation and their performance/characteristics.
- This is despite the fact people thought they were attending a ‘Wedding’ Dinner or even a “Spa” event [typo on the signage]...



LS in Tandem with L1; Future Spa-Weather Missions Workshop Dinner

Table	Guest name	Table	Guest name	Table	Guest name
4	Alan Title	7	Elena Perina	4	Matthew West
5	Alanair Pilgroun	8	Eric Adamson	2	Matthew Wood
10	Alexandre Bempourat	5	Ewan Haggerty	1	Mike Willis
7	Allen Peacock	8	Francesca Zaccarello	4	Narada Nims
8	Alan Sacha Brun	10	Frans Hill	7	Nicole Vilmer
7	Andrew Lagg	5	Gareth Lawrence	6	Noe Lopez
6	Andrew Fanklerley	9	George Ho	10	Paulo D'Araujo
			Hermann		
5	Andrew Marcham	5	Oppenoworth	9	Paolo Pagano
5	Andrew Shibley	3	Jackie Dantes	10	Philipp Vings
3	Angelos Vouraidas	9	James Chen	8	Robben Wright
3	Bernard Jackson	4	James Lemm	1	Richard Hartman
7	Bob Scerifery	7	Jesper Schau	4	Robert Leaman
			Jonathan Eastwood	6	Robert Wimmer-Schwengruber
5	Catherine Burnett	6	Jonathan Eastwood	6	Robert Wimmer-Schwengruber
4	Cathy Woods	1	Joyce Miller	8	Rui Pires
3	Chris Eyles	5	Juhani Huononen	3	Russell Howard
2	Chris Perry	1	Juha-Pekka Luutama	2	Ruth Peterson
6	Christian Mosest Christopher	1	Kent Miller	1	Sarah-Jane Sniart
2	Carmuzano	3	Luciano Rodriguez	4	Scott McIlsonsh
1	Claudia Lally	3	Luke Bernard	2	Seib Jonas
6	Clive Dyer	1	Mahsaab Siddiqui	7	Shawn Blomfield
3	Craig DeForest	2	Manolis Georgoulis	7	Sophie Murray
3	Curt de Koning	10	Marja Kummetsova	8	Sterlan Kraft
2	David Davenport	10	Mark Cheung	4	Thomas Woods
9	David Jackson	1	Mark Gibbs	9	Timo Lahtinen
4	David Long	9	Markos Trichas	2	Trevor McMaster
6	Dhruv Kataria	1	Mario Biaz	3	Volker Balthmer
4	Don Hasler	9	Matthew Perren	10	Xinlin Li
5	Douglas Besecker	8	Matthew Stuartard	6	Yulia Bogdanova

KINGSWAY HALL HOTEL  
CONVENT GARDEN





# Workshop ‘Wedding’ Dinner

## – Homework...(2)

Platform →	L1		L5		
<b>Instrumentation ↓</b>	<b>US</b>	<b>UK / ESA</b>	<b>ESA</b>	<b>UK</b>	<b>US (5)</b>
<b>Coronagraph</b>	M N/R (4)	M	M	M	M
<b>Heliospheric Imager(s)</b>	N/R M (1,4) E (3,5,6,10*)	E M (1) N/R (2) O (6)	M	M	M
<b>Magnetograph (including white-light imager)</b>	E M (1,4,9) Not necessary at L1 (10)	M N/R (4) E (5) Not necessary at L1 (10)	M N/R (4) E (5)	M E (5)	M
<b>EUV Instrumentation</b>	N/R	N/R	E M (1) N/R (5)	O N/R (5) E (6)	N/R
<b>Magnetometer</b>	M	M	M	M	E/M
<b>Bulk Plasma</b>	M	M	M	M	E/M
<b>Energetic Particles</b>	E M (9,10)	M E (5)	M E (5)	E M (9,10)	M
<b>X-ray Flux Monitor</b>	N/R E (3)	M E (1,10)	M N/R (5)	E N/R (5)	M

Part 4:

# Summary and where next?

# Summary



- Part 1: Space weather is very complex with real-world impacts, it comes in multiple strands; the most deleterious impacts caused by CME-driven geomagnetic storms, but the recent solar cycle has seen many HSS-/SIR-related storms.
- Part 2: Very successful and interactive workshop (huge level of interest for active participation) with productive presentations, discussions, and Working Group summaries. Strong social media presence ([#L1L5Together](#)). Plans going forward (see next slide).
- Part 3: It is clear that the UK still want a leading role in a dedicated  $L_5$  operational space-weather mission (the UK are the largest contributor to the ESA SSA Programme Period 3, ~€12M of which is just for  $L_5$ ). There is a strong will of participants to see an increase in the payload of the  $L_1$  mission and also for modellers and instrument developers to work together on tools, software, and instrument capabilities across both spacecraft. Strong support from ground-based space-weather capability to support future  $L_5/L_1$  space-weather missions.

# Where next?



- Already, many participants and interested parties have asked when the next workshop will be and how and where can things be done to aid in ensuring a UK/European-led  $L_5$  space-weather mission goes ahead in a timely manner.
- Active interactions across Europe involving the preparations of the ESA SSA Period 3 ITTs where the Lagrange Mission(s) (LGR) have now formed a formal part of SSA alongside SWE, SST, and NEO.
- $L_1$  is still the priority, but final NOAA confirmation of SWFO going ahead will bring  $L_5$  as a certainty going forward – almost there...
- Formal Q1/Q2 ITTs for Period 3 have been released for the mission, remote-sensing instrumentation, and *in-situ* instrumentation, and consortia are already forming up to bid for these large projects in preparation for a future  $L_5$  mission.
- SWE modelling calls to prepare for data from a  $L_5$  mission.
- There is a lot going on now in Europe – watch this space...