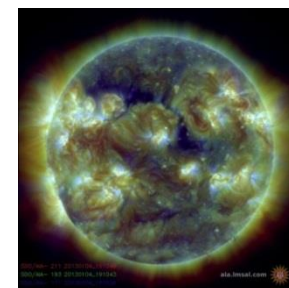
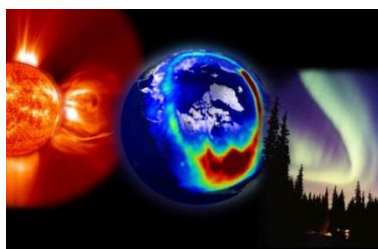


Report on the “L5 in Tandem with L1: Future Space-Weather Missions Workshop” – Steps Toward a L5 Operational SWx Mission

Mario M. Bisi (STFC RAL Space, UK) {Mario.Bisi@stfc.ac.uk},
Mark Gibbs (Met Office, UK), Douglas A. Biesecker (NOAA NWS
SWPC, USA), Mike A. Hapgood (STFC RAL Space, UK),
Pete Riley (Predictive Science, Inc., USA), and Juha-Pekka Luntama
(ESOC, Germany)

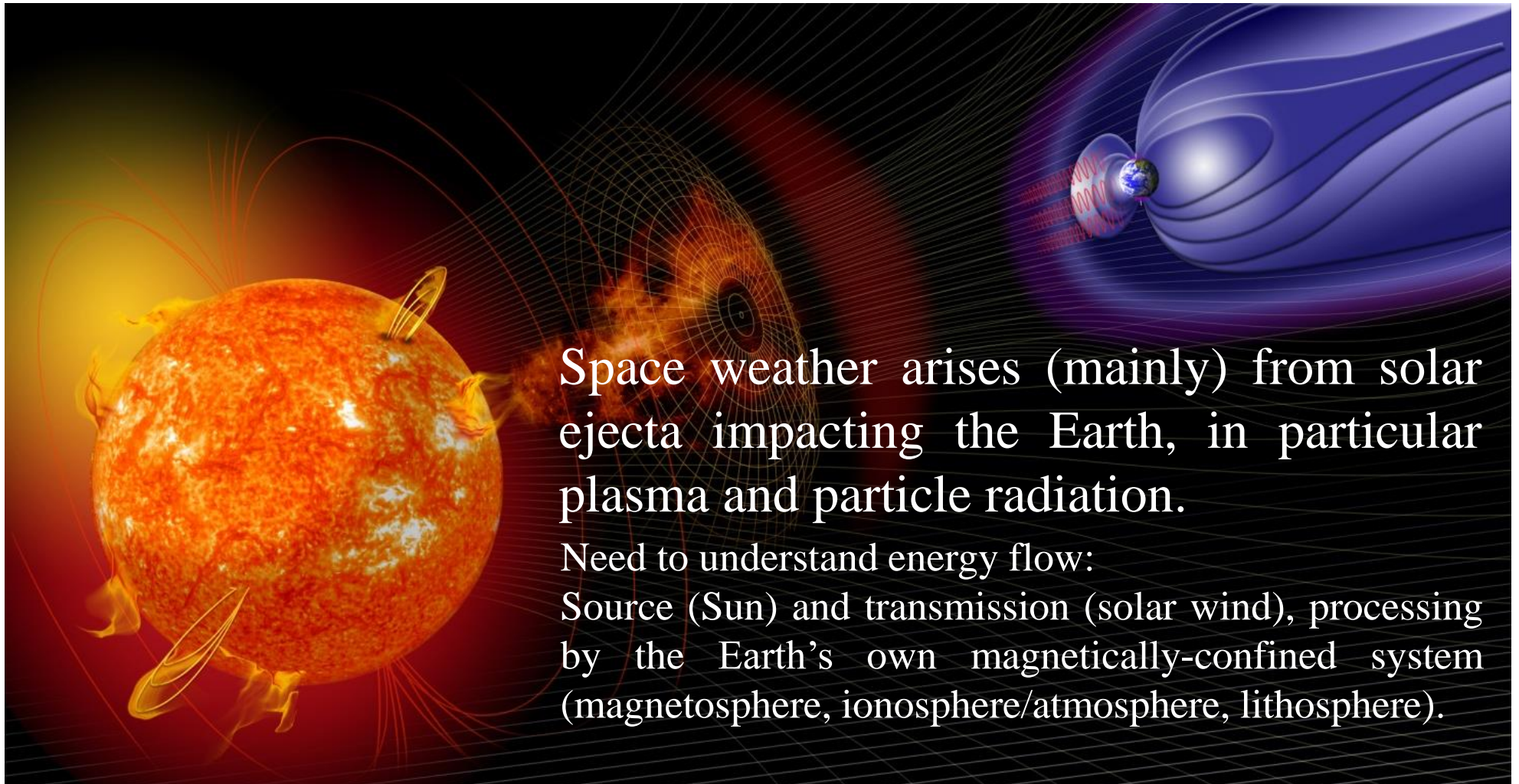


- Part 1: Why we want dedicated space-weather operations from L_5 in tandem with L_1 .
- Part 2: Outline of the “ L_5 in Tandem with L_1 : Future Space-Weather Missions Workshop”.
- Part 3: Key points from the workshop.
- Part 4: Summary and where next?

Part 1:

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

Space-Weather Focus: The Sun-Earth Connection

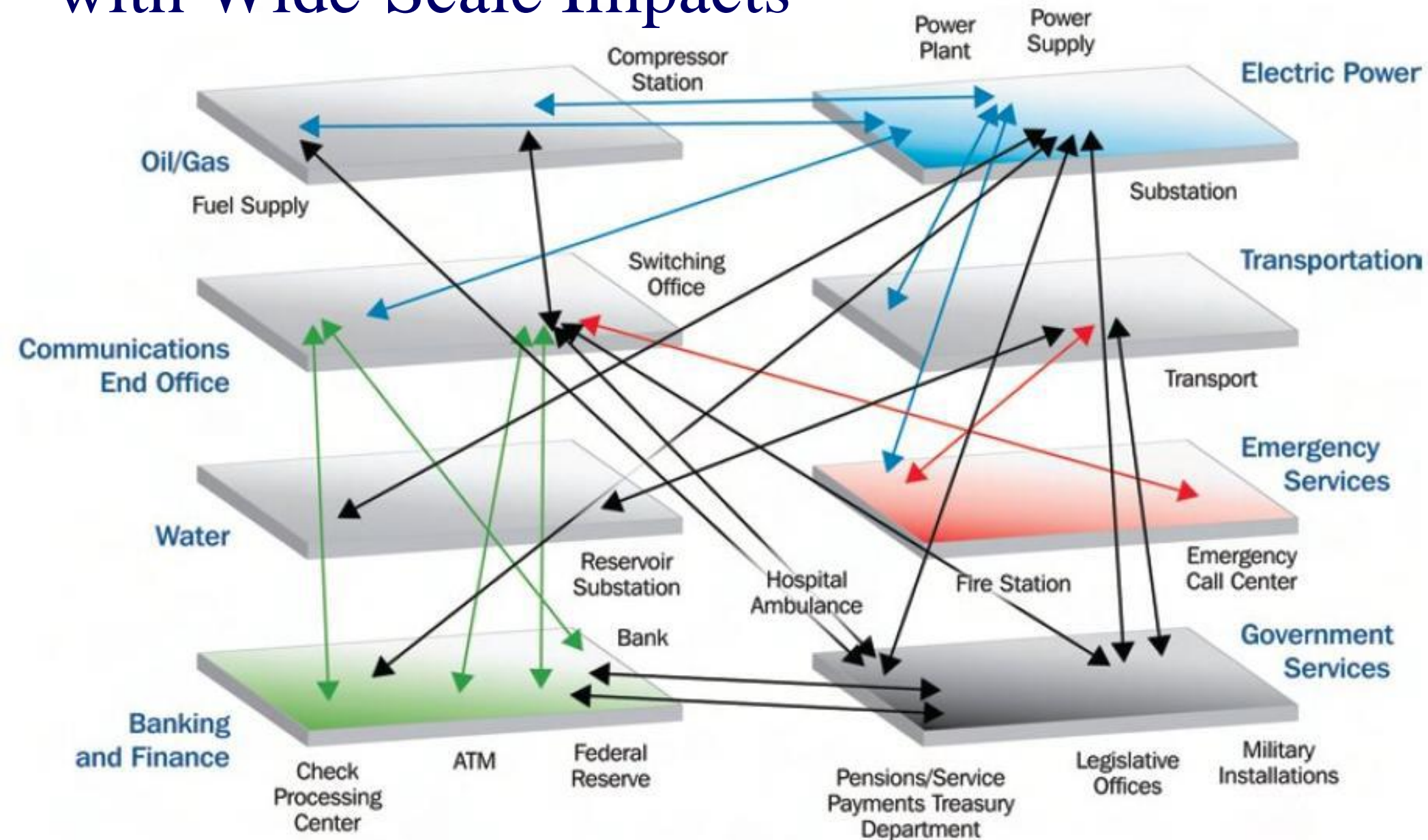


Space weather arises (mainly) from solar ejecta impacting the Earth, in particular plasma and particle radiation.

Need to understand energy flow:

Source (Sun) and transmission (solar wind), processing by the Earth's own magnetically-confined system (magnetosphere, ionosphere/atmosphere, lithosphere).

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.
- Workshop website (agenda, abstracts, and talks available, with notes upcoming): <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_5 and L_1 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_5/L_1 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_1 and L_5 operational missions can complement each other and maximise the overall benefit to the international communities.

Part 3:

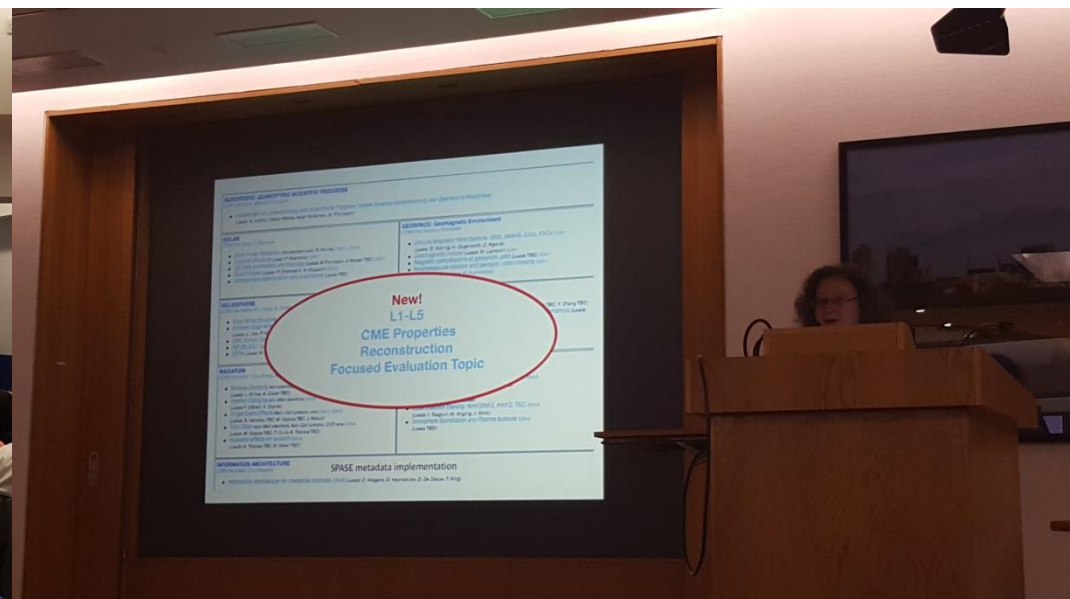
Key points from the workshop.

High-Level Key Points

- Opened by the BEIS Department Chief Scientific Advisor.
- Increasing convergence of views – both on L_5 rather than L_4 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_5 :
 - 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_5 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_5 space-weather operational mission.

Modelling Needs

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



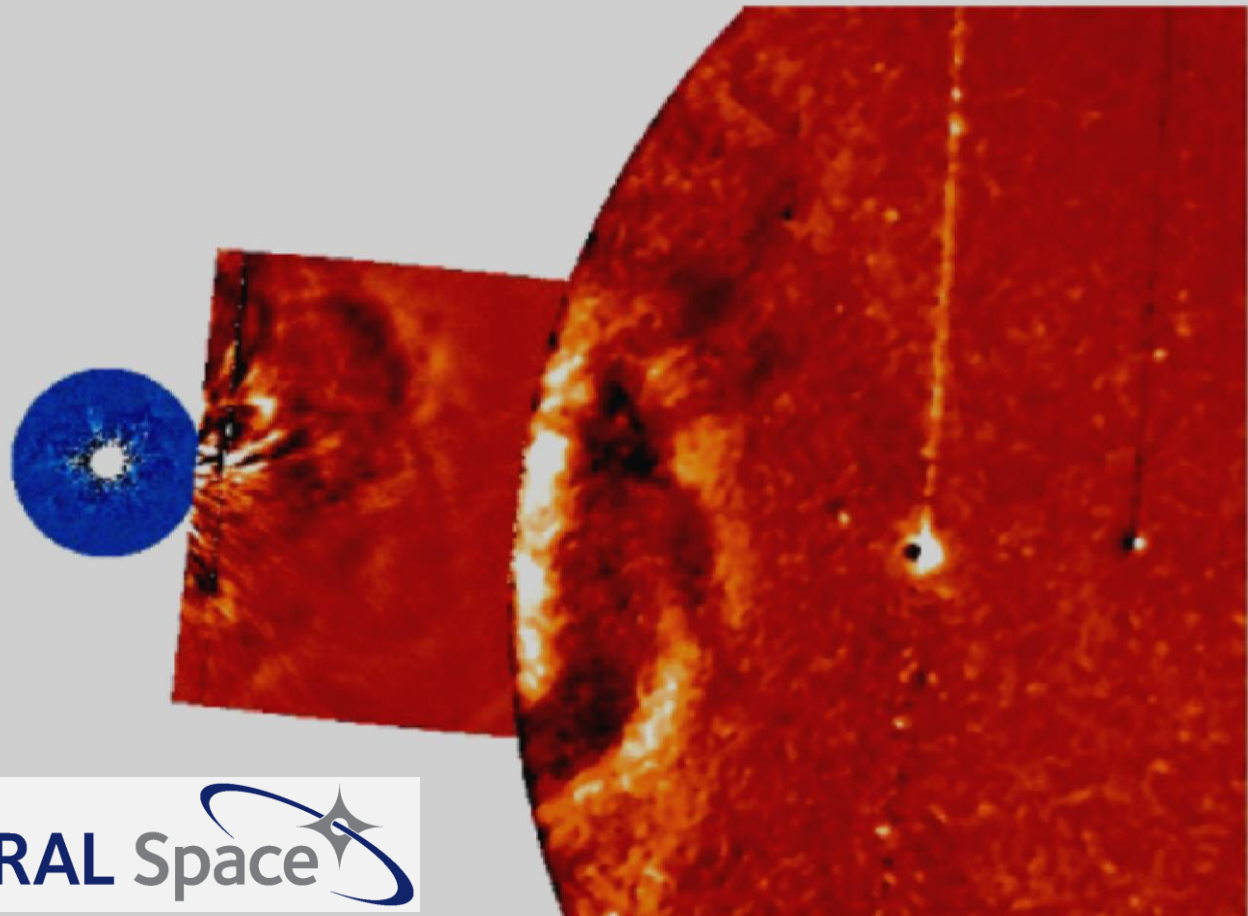
Some Other Ideas Discussed...

- 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/.
- 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_5 ...



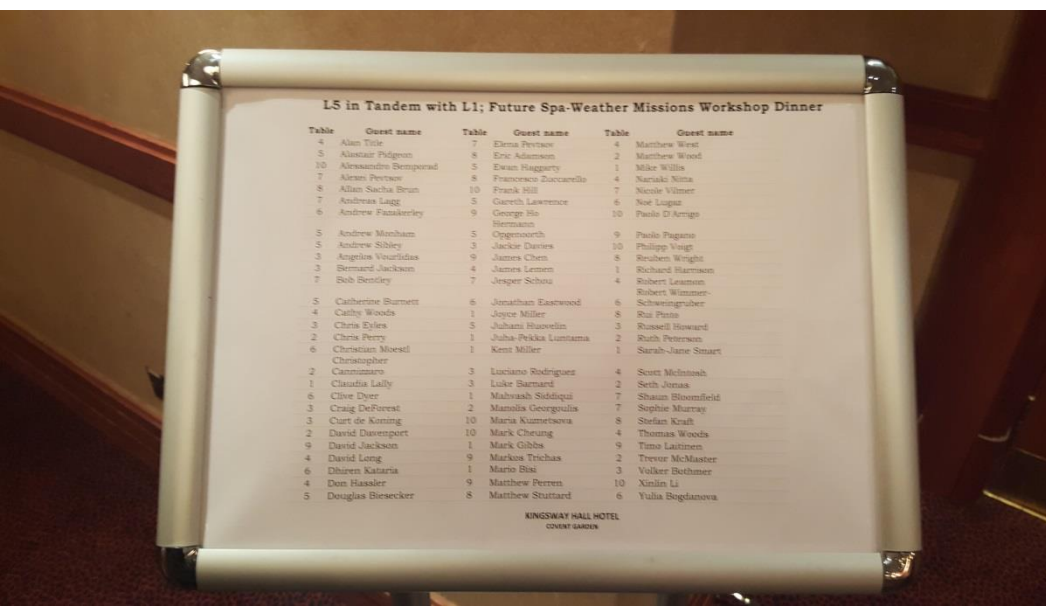
The Working Workshop...



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]...



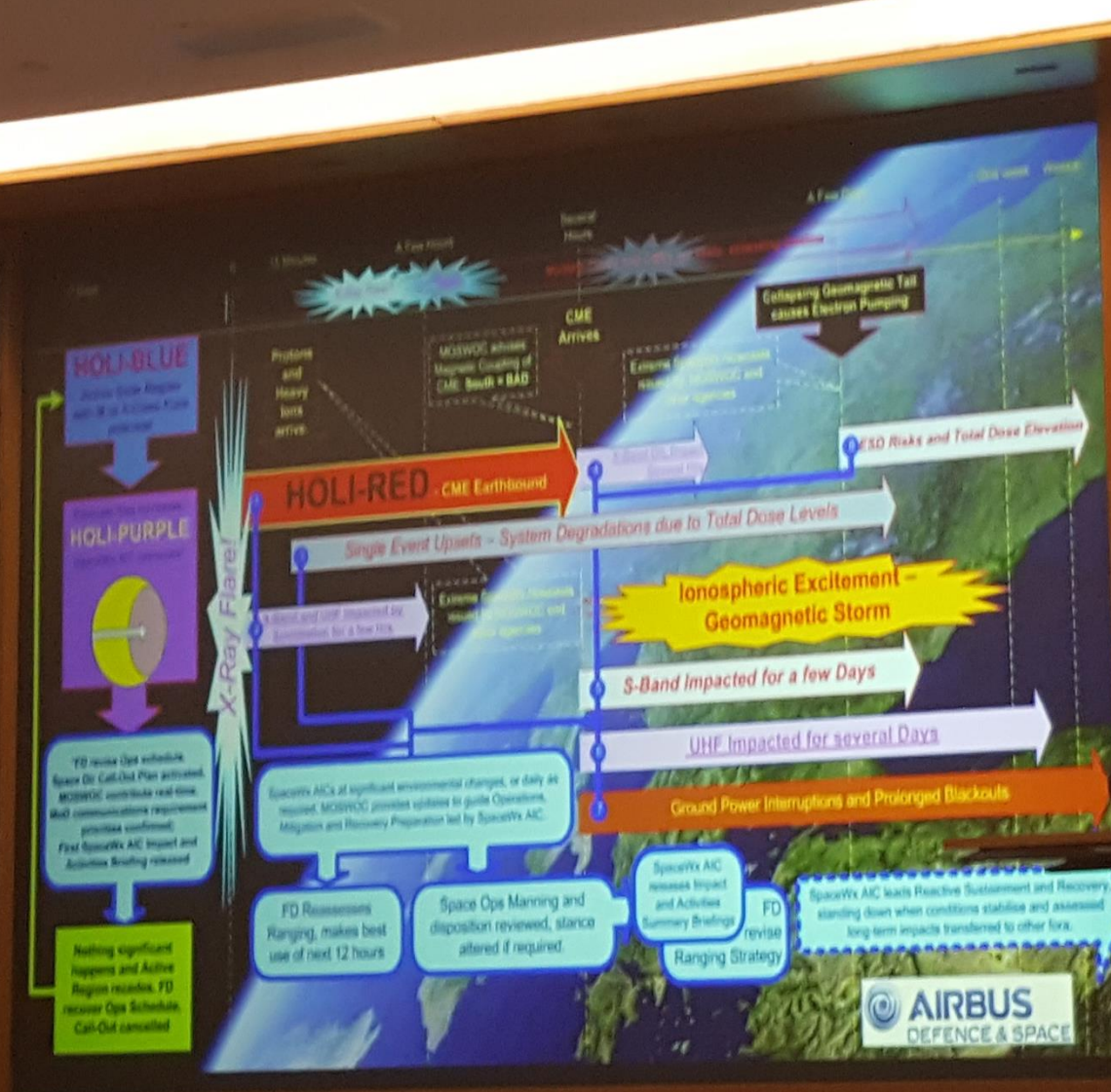
Workshop ‘Wedding’ Dinner

– Homework...(2)

Platform →	L1		L5		
Instrumentation ↓	US	UK / ESA	ESA	UK	US (5)
Coronagraph	M N/R (4)	M	M	M	M
Heliospheric Imager(s)	N/R M (1,4) E (3,5,6,10*)	E M (1) N/R (2) O (6)	M	M	M
Magnetograph (including white-light imager)	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
EUV Instrumentation	N/R	N/R	E M (1) N/R (5)	O N/R (5) E (6)	N/R
Magnetometer	M	M	M	M	E/M
Bulk Plasma	M	M	M	M	E/M
Energetic Particles	E M (9,10)	M E (5)	M E (5)	E M (9,10)	M
X-ray Flux Monitor	N/R E (3)	M E (1,10)	M N/R (5)	E N/R (5)	M

The “Worry” Chart

(Ewan Haggarty – Airbus DS (SKYNET 5 experience))



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 (and the UK are the largest contributors to the ESA SSA programme Period 3). There is a strong will of participants to see an increase 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 L₅ space-weather mission goes ahead in a timely manner.
- Active interactions involving the preparation of the ESA SSA Period 3 ITTs where the Lagrange Mission(s) (LGR) has now formed a formal part of SSA alongside SWE, SST, and NEO.
- UK General Election period of “Purdah”: we have to be very careful not to do or say anything that could be seen in any way to support any political party or candidate and as such we cannot provide anything new in a public forum that was not already made public or published prior to the commencement of Purdah...
- We have plans – but need to wait until after 8th June...