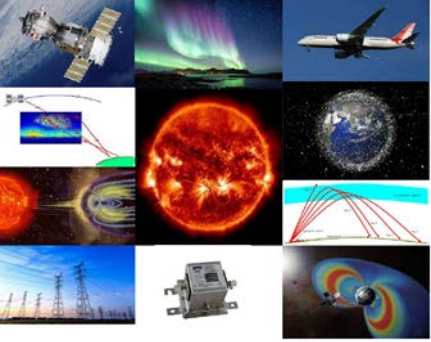


# SWIMMR

Space Weather Innovation, Measurement, Modelling and Risk  
A “Wave 2” programme of the UKRI Strategic Priorities Fund

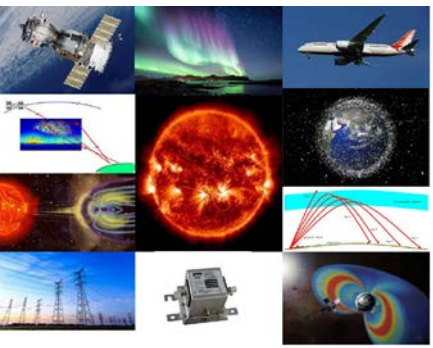
Ian McCrea

STFC Rutherford Appleton Laboratory



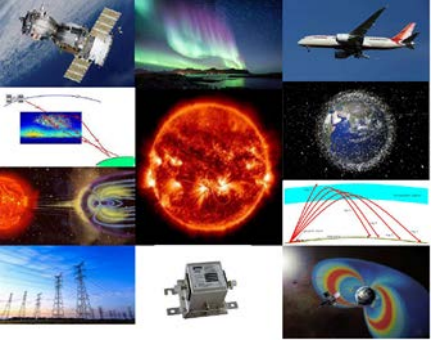
# What is SWIMMR?

- A £19.9M four-year programme in UKRI SPF Wave 2
- To develop and deploy new instruments and models to support the UK space weather community and national capabilities in MOSWOC
- Directly addresses priorities identified by BEIS, MoD and DfT
- Aimed at improving predictions and establishing a legacy of enhanced operational capabilities
- Has to complete in less than four years!



# What SWIMMR is not!

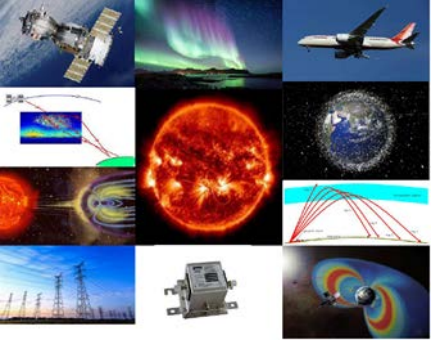
- Not intended as a vehicle for pure blue-skies research
  - This is strategic science, highly directed to government and Met Office priorities
  - Government and ministerial CSA support was crucial to the bid
- SWIMMR cannot be allowed to go off-track
  - Funding is conditional on us delivering against the scope of the proposal
  - There will be significant Monitoring and Evaluation, compared to normal grants
- SWIMMR cannot continue beyond 31/03/2023
  - There is no guarantee of an SPF Wave 3 (requires a political decision)
- Projects need to stick closely to budget and schedule
  - Financial re-profiling of the project will be difficult



# The SWIMMR Programme



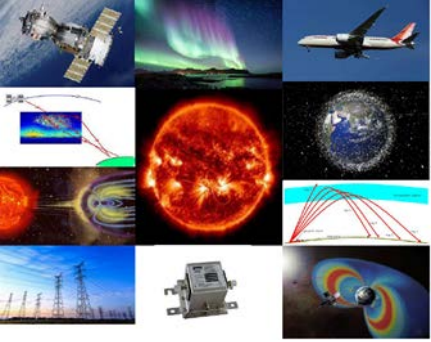
- Eleven projects, divided almost equally between STFC and NERC
- Delivered through STFC:
  - S1: In-situ radiation measurements for space and aviation (budget £5.7M)
  - S2: Support for technology testing and modelling (budget £600k)
  - S3: Support for the transition from research to operations (budget £900k)
  - S4: Forecasting from the Sun to L1 (budget £450k)
  - S5: Support for a ground radiation monitoring network (budget £1.4M)
  - S6: Production of an updated space weather impact study (budget £300K)



# The SWIMMR Programme



- Delivered through NERC
  - N1: Improvement of satellite risk forecasts (budget £2M)
  - N2: Improvement of aviation risk forecasts (budget £2M)
  - N3: Improved forecasting for GNSS and HF communications (budget £2M)
  - N4: Improved forecasting of ground level current effects (budget £1.7M)
  - N5: Improved forecasts of satellite drag (budget £1M)
- These five NERC topics are covered by a single [Announcement of Opportunity](#), released last month (November 26<sup>th</sup>)



# Delivery Mechanisms

- Projects N1 to N5 will all be delivered through NERC grants
  - Three year grants, ending spring 2023
  - Means that all grants have to start in spring 2020
- We expect one grant to be awarded per project
  - Expectation therefore is, therefore, that projects will be consortium bids
  - Note that no more than two projects can have the same PI
- Proposers should discuss with UKMO
  - Met Office are holding a SWIMMR “bidders day” on Dec 19<sup>th</sup>

# NERC Grant Call Projects

## N1: Improvement of satellite risk forecasts

### Context

- Growing dependency on space based infrastructure
- Key importance of UK commercial/governmental assets at GEO
- Increasing utilisation of MEO
- Massive increase in satellite constellations at LEO, with UK licensing

### Aim

- Need improved real time nowcast & forecast capability
  - multiple orbits
  - range of impacts
  - accuracy

# NERC Grant Call Projects

## N1: Improvement of satellite risk forecasts

### Deliverables/Methods

- NRT forecast of high energy electron radiation for user defined orbits in GEO, MEO & LEO
- Forecasts of risk of internal charging, dose, non-ionising dose and single event upsets along specified satellite orbits in LEO, MEO and GEO
- Forecast of risk of damage or degradation due to trapped particle radiation
- Nowcast of risk of damage due to surface charging and sources such as SEPs
- Ingestion & model driven by suitable data sources
- Support operational implementation in MOSWOC
- Validation & verification



# NERC Grant Call Projects

## N2: Improvement of aviation risk forecasts

### Context

- Significant governmental interest in safety standards for avionics
- Radiation dose concern for aircrew & passengers
- Radiation resilience of hardware
- Now part of ICAO Space Weather Advisory Service
- No UK capability to support response to a severe event

### Aim

- MOSWOC capability to nowcast, retrospectively attribute and potentially forecast SEP/GCR effects

# NERC Grant Call Projects

## N2: Improvement of aviation risk forecasts

### Deliverables/Methods:

- Global-scale 3D near real-time information and alerts for SEP (& GCR) impact for aircraft avionics, passengers and crew
  - retrospective, nowcast and potentially forecast
- Account for concurrent geomagnetic disturbances in admitting solar particles to lower latitudes.
- Ingest suitable data from ground, airborne and space networks to drive models in near real time (especially S1 & S5)
- Support operational implementation in MOSWOC
- Validation & verification

Note: should be capable of meeting ICAO and other service thresholds

# NERC Grant Call Projects

## N3: Effects on GNSS and HF communications

### Context

- Growing dependence on GNSS
- Reliance on augmentation systems (SBAS) derived from GPS
- HF comms continue to be important for aviation & military
- Inclusion in remit of ICAO Space Weather Advisory Service

### Aim

- MOSWOC capability for real-time forecast/nowcast of global ionosphere
- Predictions of regional ionospheric conditions (scintillation and comms)
- Ability to offer products relevant to aircraft routing, approach and landing

# NERC Grant Call Projects

## N3: Effects on GNSS and HF communications

### Deliverables/Methods:

- Coupled NRT ionosphere-thermosphere 3D assimilative forecast model.
- Assimilate range of data including
  - satellite orbit and accelerometer data,
  - thermospheric radiance data,
  - electron density profiles or virtual height profiles,
  - total electron content (TEC).
- Regional mapping of TIDs and/or TEC gradients.
- Low and high latitude scintillation mapping.
- Capable of delivering relevant GNSS, SBAS and HF products.
- Support operational implementation in MOSWOC following validation & verification

Note: should be capable of meeting ICAO and other service thresholds

# NERC Grant Call Projects

## N5: Space weather effects on satellite drag

### Context

- Development of UK sovereign launch strategy
- Significant expansion in UK funded/licensed satellite constellations
- Likely development of independent UK SST capability (NSpOC)

### Aim

- Met Office ability for forecasts and nowcasts for objects in LEO
- Real-time ability to assess increased risks of collision and re-entry

# NERC Grant Call Projects

## N5: Space weather effects on satellite drag

### Methods/Deliverables

- Coupled NRT ionosphere-thermosphere 3D assimilative forecast model.
- Assimilate range of data including
  - satellite orbit and accelerometer data,
  - thermospheric radiance data,
  - electron density profiles or virtual height profiles,
  - total electron content (TEC).
- A system level model capable of meeting the satellite orbit nowcasting and forecasting objectives.
- Support operational implementation in MOSWOC
- Validation & verification

# NERC Grant Call Projects

## N4: Ground level current effects

### Context

- Risks to power grid through induced quasi-DC currents
- Potential transformer damage and tripping, harmonics, instability
- Enhanced pipe-soil potential in pipeline networks
- Risk of enhanced corrosion
- Potential signalling issues in rail transport

### Aim

- MOSWOC forecasts and nowcasts of geoelectric field
- Specific predictions of effects on ground level conductors
- Sufficiently targeted information to allow mitigation in real time

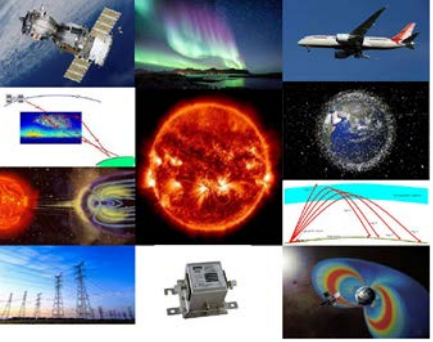
# NERC Grant Call Projects

## N4: Ground level current effects

### Methods/Deliverables

- NRT nowcast and forecast of ground-level geomagnetic and geoelectric fields across the UK.
- Nowcasts and forecasts of GIC in the UK high-voltage electricity transmission network.
- Nowcasts and forecasts of PSP in the UK high-pressure gas transmission network.
- May need improved geomagnetic survey data to enable specific prediction
- In conjunction with the Met Office, a system of web displays that are updated by the forecasts and nowcasts.
- Support operational implementation in MOSWOC
- Validation & verification





# NERC Announcement of Opportunity



- The timetable for the NERC AO is quite rapid:
  - Announcement published: 26/11/19
  - Call opens in Jes 04/12/19
  - Consultation with UKMO before: 15/01/20 (Bidders Day 19/12/19)
  - Submission of proposals: 30/01/20
  - Peer review assessment: Mid-March 2020
  - Awards notified by: 01/04/20
  - Grants begin by: 01/06/20
  - End date of awards: 31/03/23
- Peer review will be done by expert panel, to which proposers will be invited to present and answer questions.

# Specific Features of the NERC AO (1)

Some non-standard features compared to normal NERC calls:

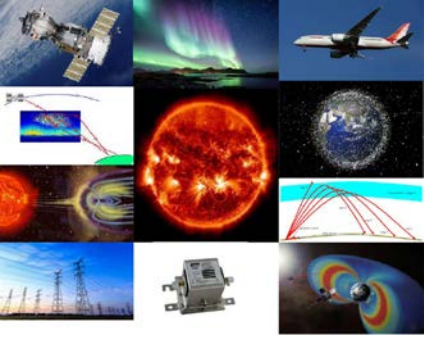
- A single person cannot be PI for more than two projects
- Need to provide milestones and delivery plan
  - The NERC AO contains suggested milestones
  - Deviations are OK, but should be justified
- Expected that some research may be needed to underpin model/service development
  - Some suggested research areas are listed in the AO
- Requirements on models
  - Near real time data assimilation,
  - Resilient, autonomous model running
  - Appropriate documentation
  - Fit to the MOSWOC R2O environment (Amazon Web Services)
  - Models running on HPC should be parallelised if possible

# Specific Features of the NERC AO (2)

- Specific requirements on licensing agreements with Met Office
  - Royalty free, non-exclusive model licence to MOSWOC, need to document in Impact section
  - Licences and terms of use for any input data
  - Does not affect the developers' IPR
- Specific requirements on progress reporting
  - Short progress report every three months, also normal Research Fish
  - Final reports at end of project
  - Requirements to attend and report at SWIMMR meetings
- Table of compliance to be included in the submission
  - List things requested in AO and document whether provided (if not, why not)
- Demonstrate ongoing liaison with Met Office
  - Prior consultation strongly encouraged, hence today's event

# Peer Review of NERC Proposals

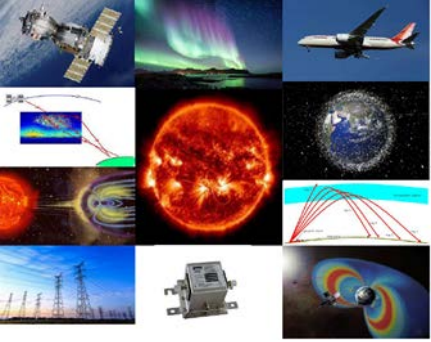
- Peer review designed to be streamlined with grants in Spring 2020
- Single stage application process
- Review based on Excellence, Fit to Scheme, Pathways to Impact
- Probably only one grant awarded per project call
- Review by expert international panel (not NERC grant panel)
  - Likely to be March 25-27, probably in London
  - PIs will present to panel and take questions
  - Clarification at panel will be important part of the assessment
  - Panel will provide (one time) feedback on all proposals
  - Governmental stakeholders will also be invited



# Key Individuals and Roles

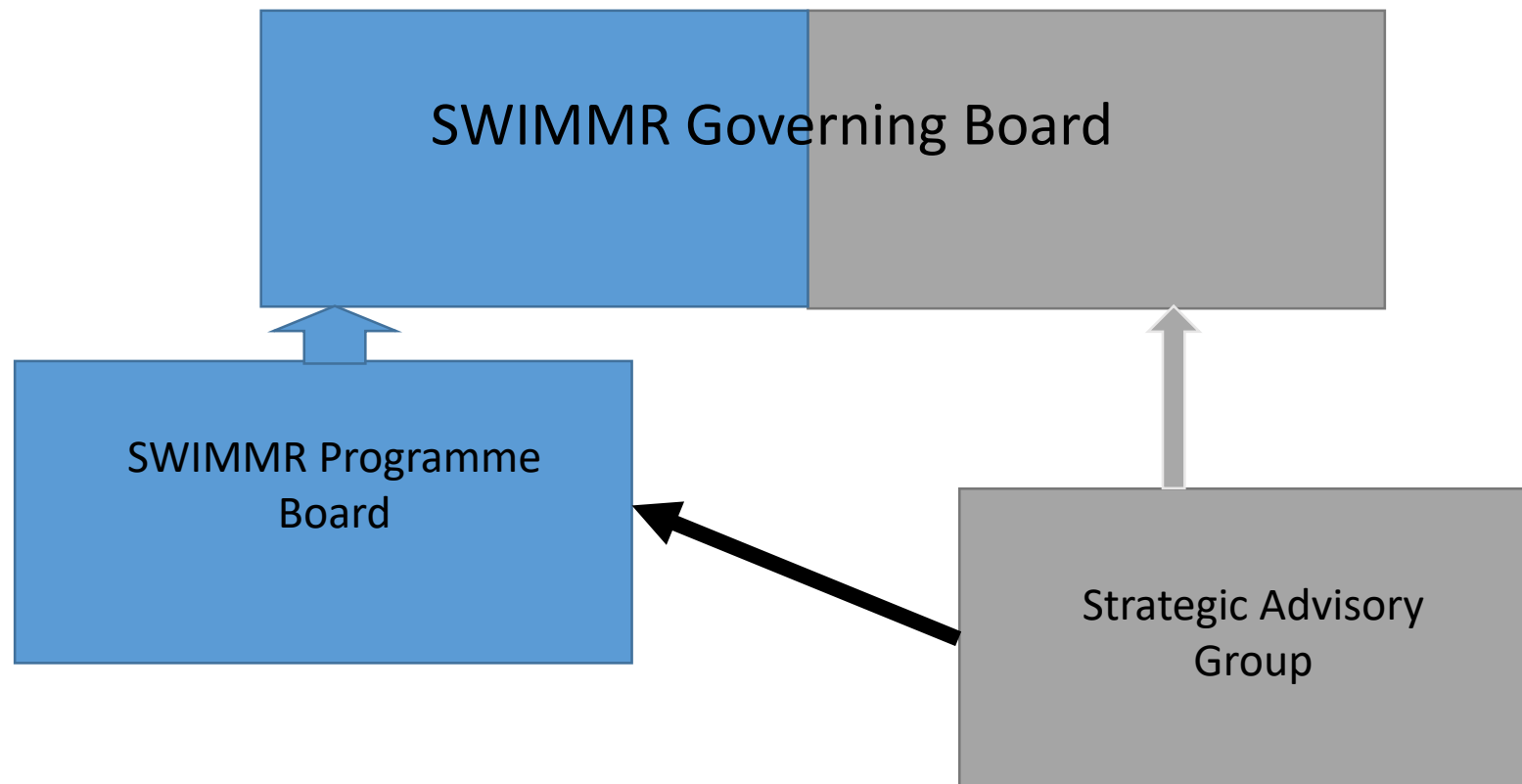


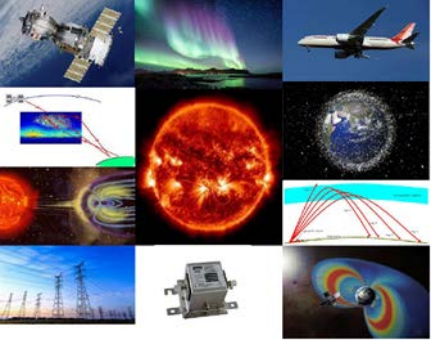
- Prof Chris Mutlow – Senior Responsible Owner
- Jacky Wood – NERC Programme Office Lead
- Justin O’Byrne - STFC Programme Office Lead
- Simon Machin and Mark Gibbs – UKMO members of PB and SAG
- Dr Ian McCrea – Senior Programme Manager
- Mila de Vere, Toni Cullum (+others) – Project Managers in STFC and NERC
  
- Olivia Greenall, Dr Gemma Attrill, Asher Lawrence-Cole – representatives of BEIS, MoD and DfT respectively



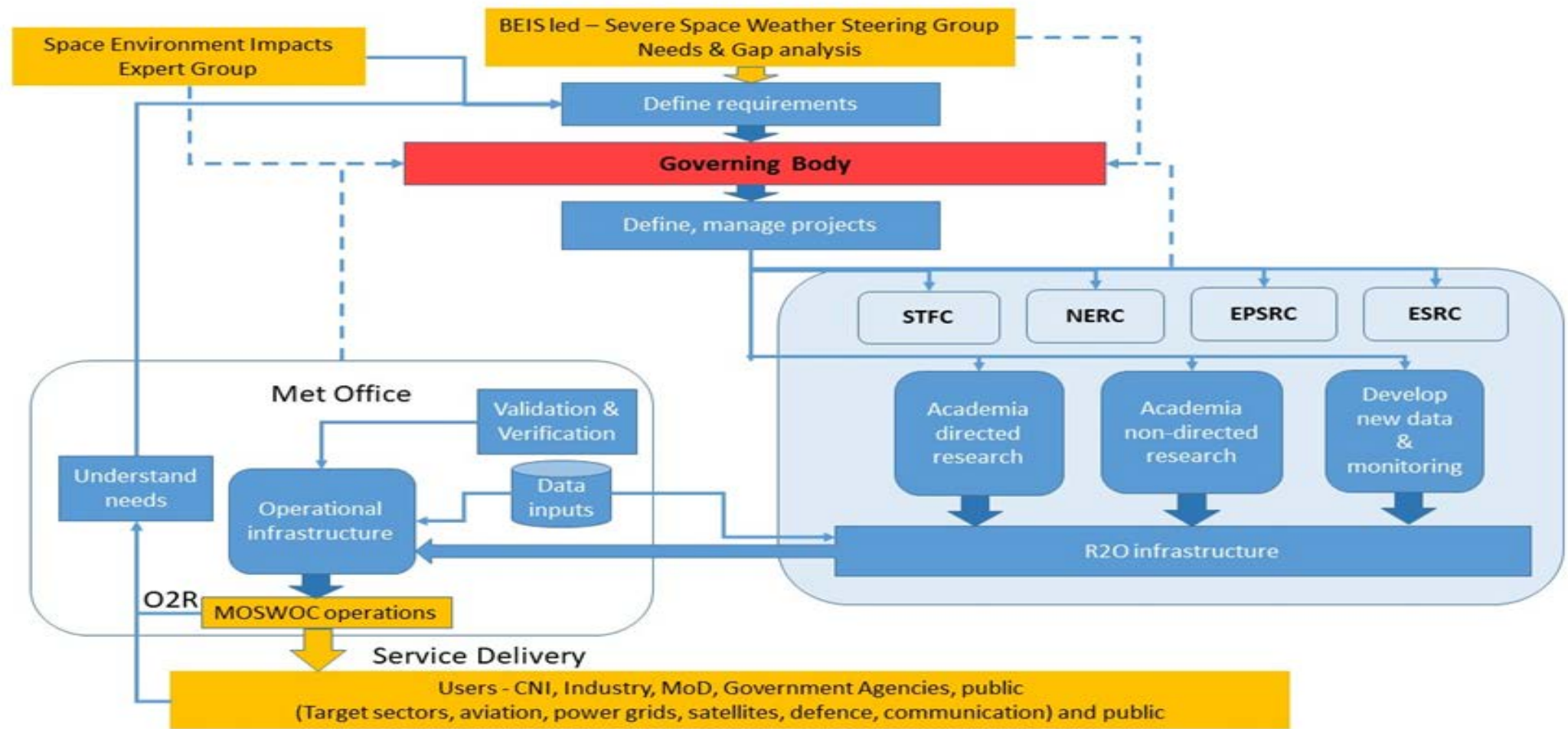
# Project Governance

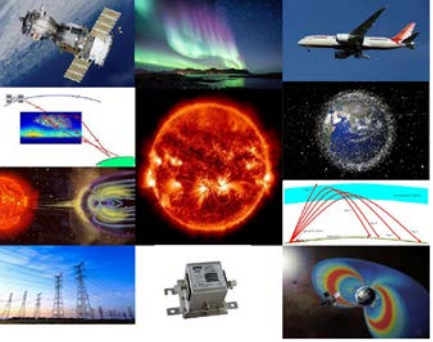
- The SWIMMR Governance model comprises three committees:





# UK Space Weather Relationships





# Top-level SWIMMR budget



- The programme is budgeted “in year”, in terms of funds transferred by BEIS to UKRI
- This annularity will not be visible in multi-year grant awards!
- Note the slow start in year 1, because we anticipated delayed approval

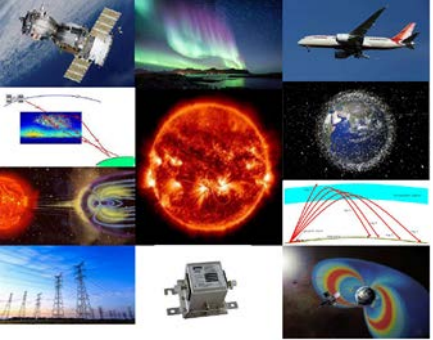
	FY19/20	FY20/21	FY21/22	FY22/23	Totals £M
STFC Programme	0.35	3.08	3.03	2.89	9.35
STFC Management	0.13	0.13	0.13	0.13	0.52
STFC OpEx	0.06	0.08	0.08	0.07	0.29
NERC Programme		2.92	2.97	3.38	9.27
NERC Management	0.03	0.09	0.08	0.08	0.28
NERC OpEx	0.06	0.07	0.07	0.08	0.28
<b>TOTAL</b>	<b>0.63</b>	<b>6.37</b>	<b>6.36</b>	<b>6.63</b>	<b>19.99</b>





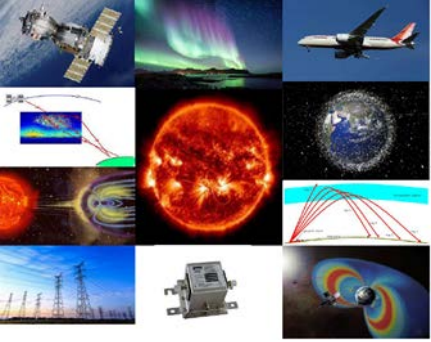






# Budget by STFC project

Project Number and Name	Lead Council	FY 19/20	FY 20/21	FY 21/22	FY 22/23	TOTAL £M
S1: Improved in-situ radiation measurements for space and aviation	STFC	0.20	1.80	1.83	1.87	5.70
S2: Technology testing and modelling	STFC	0.10	0.19	0.20	0.11	0.60
S3: Research to Operations support	STFC	0.05	0.29	0.30	0.26	0.90
S4: Forecasting from Sun to L1	STFC		0.15	0.15	0.15	0.45
S5: Ground radiation monitor network	STFC		0.55	0.45	0.40	1.40
S6: Space weather impact study	STFC		0.10	0.10	0.10	0.30
<b>TOTAL STFC Programme Budget by Year</b>		<b>0.35</b>	<b>3.08</b>	<b>3.03</b>	<b>2.89</b>	<b>9.35</b>



# Budget by NERC project



Project Number and Name	Lead Council	FY 19/20	FY 20/21	FY 21/22	FY 22/23	TOTAL £M
N1: Satellite risk forecast	NERC		0.67	0.70	0.80	2.17
N2: Aviation risk forecast	NERC		0.67	0.70	0.80	2.17
N3: GNSS aviation services forecast	NERC		0.67	0.70	0.80	2.17
N4: Ground effects forecast	NERC		0.55	0.55	0.64	1.74
N5: Satellite drag forecast	NERC		0.34	0.34	0.34	1.02
<b>TOTAL NERC Programme Budget by Year</b>		<b>0</b>	<b>2.90</b>	<b>2.99</b>	<b>3.38</b>	<b>9.27</b>

# Remaining STFC Budgets (to RAL Space)

- Funding coming to RAL Space is as follows:
  - STDA001375: Programme Management Line
    - Total budget £520k (£130k per year for next four FY)
    - Covers staff time for me, Mila, Gerard and Toni plus small elements of other staff within STFC for technical support
    - Costs of meetings and events including the PB and SAG.
  - STDA001376: Project S1: In-situ radiation measurements for space and aviation
    - Total budget £5.7M (FY19/20 £200k, FY 20/21 £1.80M, FY21/22 £1.83M, FY 22/23 £1.87M)
    - Covers scoping, design, assembly/integration, flight and data return
  - STDA001377: Project S2: Support for technology testing and modelling
    - Total budget £600k (FY19/20 £100k, FY20/21 £190k, FY21/22 £200k, FY22/23 £110k)
    - Covers upgrade and user support for use of facilities (mainly STFC ChipIR at ISIS)
  - STDA001378: Project S3: Support for the transition from research to operations
    - Total budget £900k (FY19/20 £50k, FY20/21 £290k , FY21/22 £300k, FY22/23 £260k)
    - Covers scoping, production and testing of R2O user environment

# STFC Delivery Mechanisms

- Budgets for S4, S5 and S6 (and STFC OpEx) remain at STFC Programme Office (Swindon). Justin O'Byrne and Sarah Garlick taking care of this.
- Project funding will be disbursed by Announcements of Opportunity, like the NERC AO, the first of which will go out early next year
- These are smaller than the NERC projects, so grants can be a little shorter duration
- ~~We don't have to worry about these too much, beyond helping set up the AO and the peer review mechanism (as we are doing with NERC)~~

# PRISM Status

- None of these cost codes exist in PRISM yet
- Our staff costs will be mainly in STDA001375
  - Significant effort needs to be recharged for work done earlier
  - We can recharge for set-up effort since the “soft start” in July
- STDA 1376, 1377, 1378 will be mainly used for external contracts
  - One SSA with UKMO (on project S3) is fairly advanced
  - Waiting for a detailed quote from Mark Gibbs



# Projected Year 1 Spend

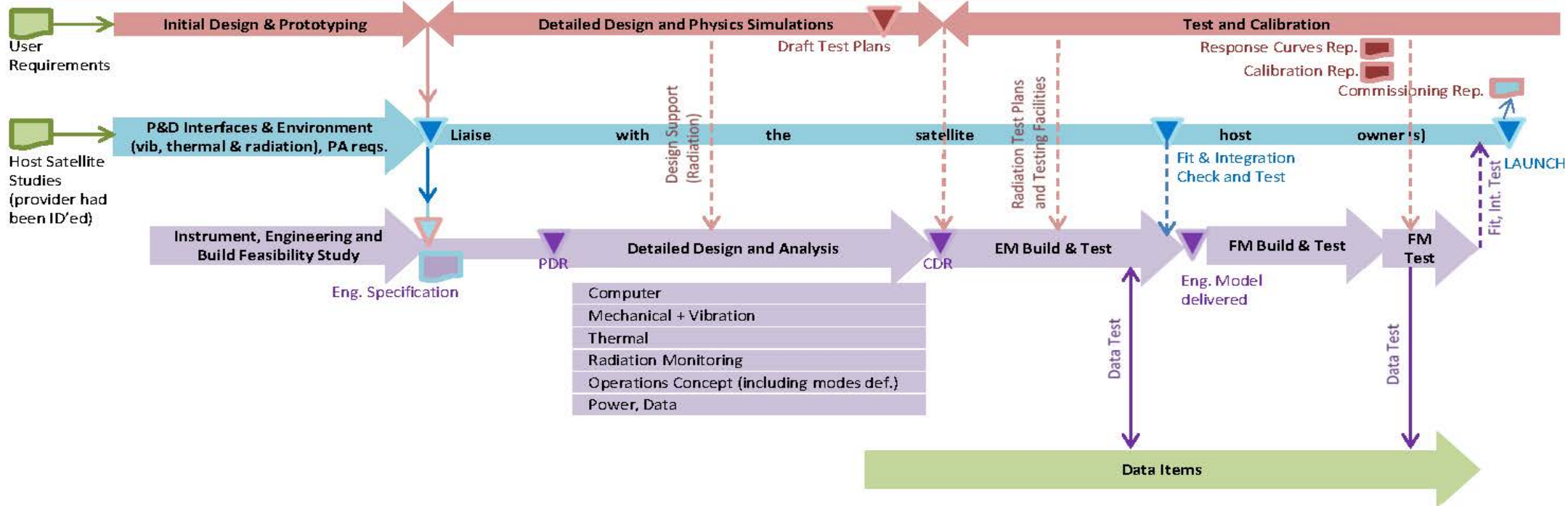
- Year 1 STFC RAL Space budget £480k for FY18/19
- Year 1 budget is already descoped due to the late start
- We will probably slightly underspend, but should be able to manage this internally (maybe 10%)
  - Management: Budget £130k, Anticipate £90-100k spend
  - S1: Radiation Monitors: Need to make some hardware purchases if we are going to get close to target (budget £200k, will only spend > £100k if we buy some hardware items)
  - S2: ChipIR: Could spend more by supporting DT hardware upgrade (Budget £100k, could spend £150-200k and reduce future years)
  - S3: Research to Operations Framework: Single Source Contract being drawn up now. Budget £50k, will spend at least this, Met Office SSA
- Underspend on management and radiation monitors can be offset by overspend on support for ChipIR upgrade (already discussed with ISIS)
- Ultimate agreement for this would have to come from Programme Board

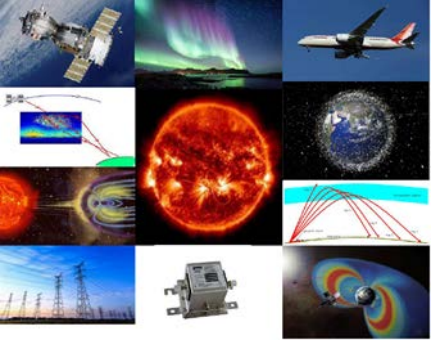
Year 2 (01/04/20-31/03/21)

Year 3 (01/04/21-31/03/22)

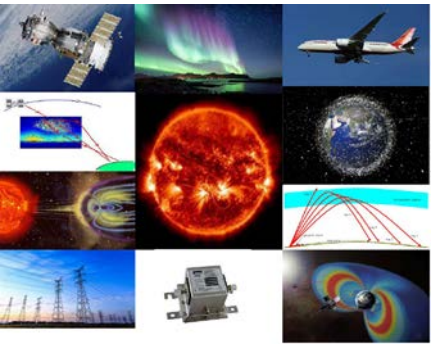
Year 4 (01/04/22-31/03/23)

### Trusted Detector Physics, Design and Support



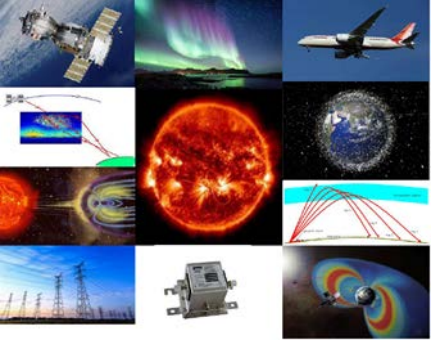


For more details of the individual projects, see Mark Gibbs's presentation coming next!



# Motivation

- MOSWOC created by importing SWPC capability
- No UK space weather research programme results in continued dependence on US
- Lack of diversity in models
- Cost if transitioning research into operations is expensive

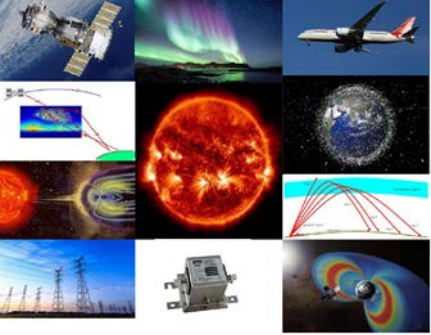


# Met Office Space Weather Operations Centre (MOSWOC)



- Fully integrated within Met Office Operations Centre
- National capability supporting;
  - Government, military & critical sectors
- 1 dedicated forecaster on duty 24/7
  - Mutual back-up with Volcanic Ash Advisory Centre position
- One of only 3 24/7 manned centres globally





# Growing user base (number & criticality)

## Existing users

- Government & CNI operators
  - E.g. National Grid, satellite operators, CAA, etc
- UK military Skynet secure communications satellites

## New /developing users

- UK Space Operation Centre (SpOC / NSpOC)
- ICAO Global Space Weather Centre
- UK spaceport
- UK satellite constellations

**Space Weather Product**  
For Airbus D&S Skynet  
Forecast issued on: Sunday, 10 September 2017      Time of Issue 18:01 Local

---

**Airbus D&S Skynet –HOLI-RED**  
**Threat Origin:**      **Active Region No. AR2673.**      **Location: N11W94.**

Probability of X-class Flares:      10 percent.  
Probability of M-class Flares:      30 Percent.

- **HOLI-BLUE** is issued when a Solar Feature has potential to cause Extreme Space Weather.
- **HOLI-PURPLE** is issued when a Solar Feature is expected to be a source of Extreme Space Weather.
- **HOLI-RED** is issued when a Solar Feature has produced Extreme Space Weather which demands SMA mitigating action.

**Forecaster Comment:** An R3 flare erupted from sunspot region AR2673. This was situated around the west limb of the solar disc. A proton response has been observed, with an S1 storm underway. There is a chance for a Strong S3 storm. Whilst a CME is possible, this has yet to be observed, and is unlikely to be Earth directed due to the location of the flare. However this requires further analysis.

**Synoptic Map: 0800 UTC.**

**Met Office Space Weather Operations Centre (MOSWOC)**  
**Space Weather Impact on Communications and GNSS - UK Region Assessment**  
Issued: 05 January 2018

05 January 2018	0001 Z to 0600 Z								0600 Z to 1200 Z								1200 Z to 1800 Z								1800 Z to 2400 Z										
	VLF/LF	MF/HF	VHF/UHF	SHF/EHF	Single band	Dual band	Time		VLF/LF	MF/HF	VHF/UHF	SHF/EHF	Single band	Dual band	Time		VLF/LF	MF/HF	VHF/UHF	SHF/EHF	Single band	Dual band	Time		VLF/LF	MF/HF	VHF/UHF	SHF/EHF	Single band	Dual band	Time				
Terrestrial Comms	F	F	F	F	F	F		F	F	F	F	F	F		F	F	F	F	F	F		F	F	F	F	F	F		F	F	F	F	F	F	
Satellite Comms																																			
GPS/GNSS																																			

Comments: Low risk of minor comms impacts at high latitudes

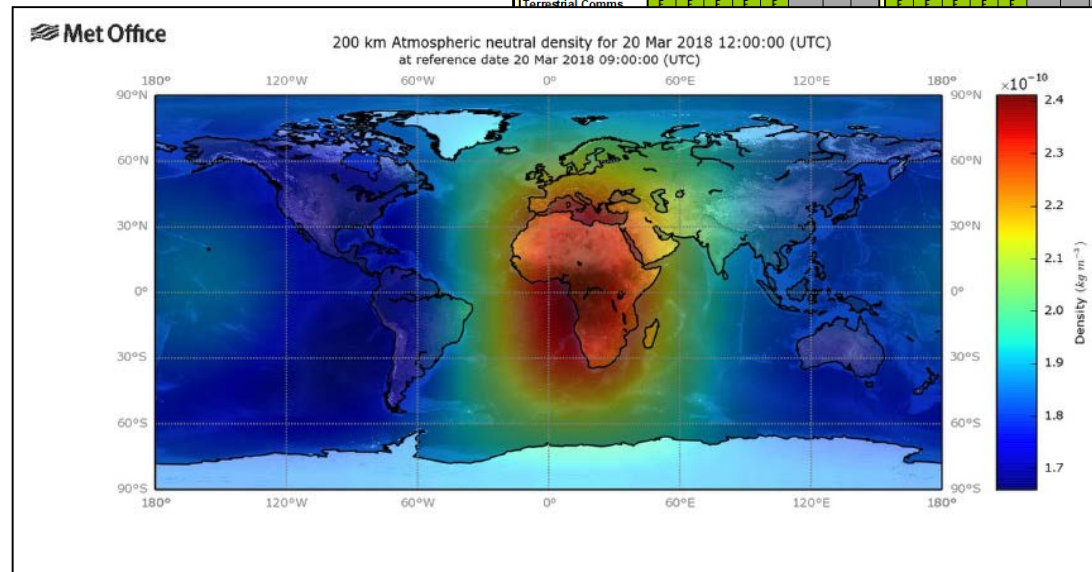
  

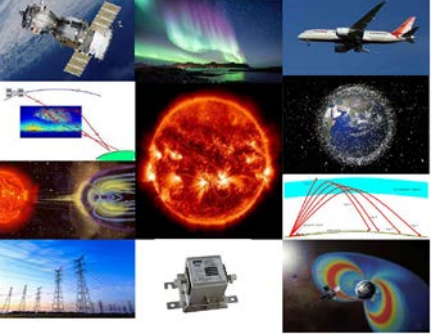
07 January 2018	0001 Z to 1200 Z								1200 Z to 2400 Z							
	VLF/LF	MF/HF	VHF/UHF	SHF/EHF	Single band	Dual band	Time		VLF/LF	MF/HF	VHF/UHF	SHF/EHF	Single band	Dual band	Time	
Terrestrial Comms	M	M	S	S	S			S	S	S	S	F				
Satellite			M	M	S			S	S	F						
GPS/GNSS								S	S	S						

Comments: Low risk of minor comms impacts at high latitudes

**SS Timing**  
 - unlikely to be unreliable with normal sustained use of timing service.  
 - likely to be occasionally unreliable.  
 - may be unreliable for short periods.  
 - timing not impacted due to weather.

**Self Select Look-Up**  
(Period - System - Frequency)  
 Forecast Period: 06 Jan, 0001 Z to 1200 Z  
 System Type (Comms or GNSS): GNSS      Frequency or GNSS type/timing:      Time:      **Slight Degradation**





# Why SWIMMR?

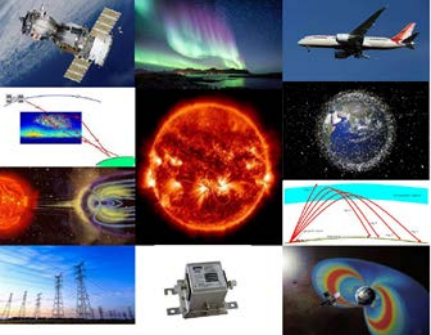
## 1. Fill capability gaps (now & future)

- Radiation effects
- Ionospheric impacts – navigation & communications
- Atmospheric density (orbit determination & collision risk)
- Electric-field modelling

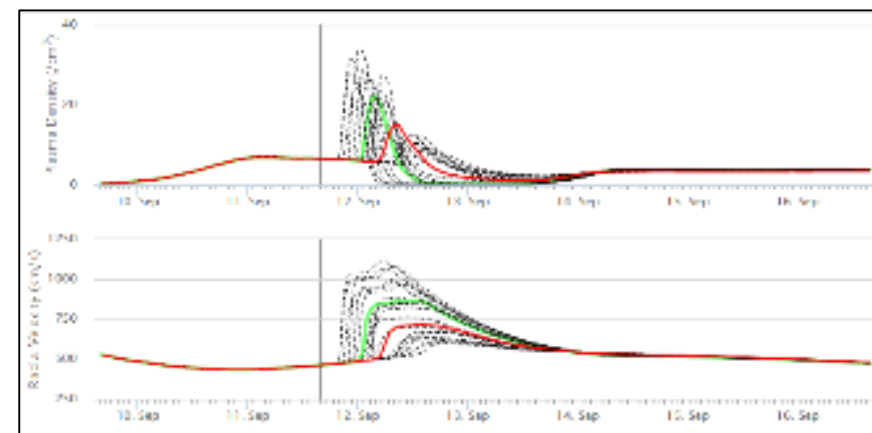
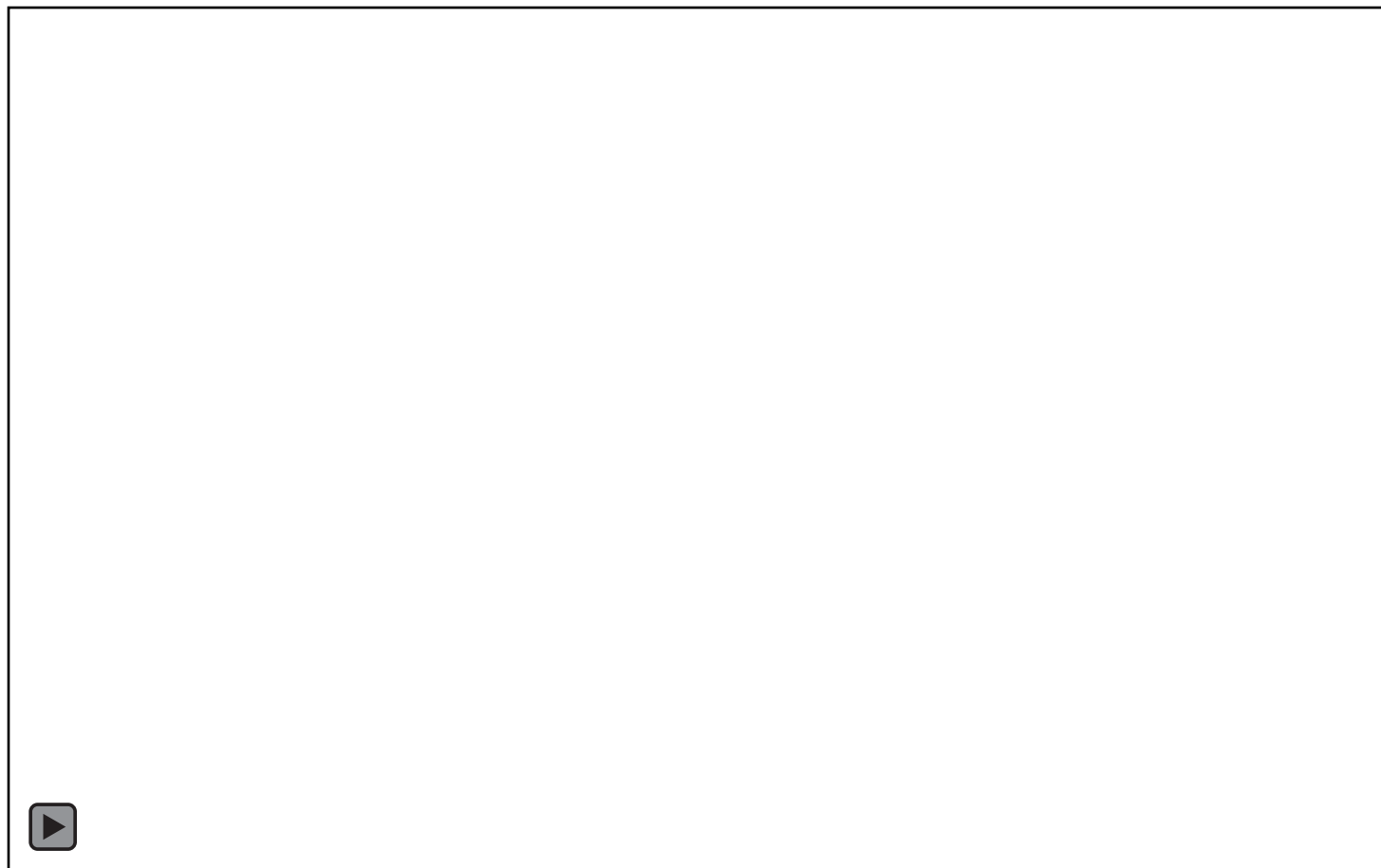
## 2. Utilise UK knowledge & capability

- Showcase UK science
- Create diversity in forecast solutions

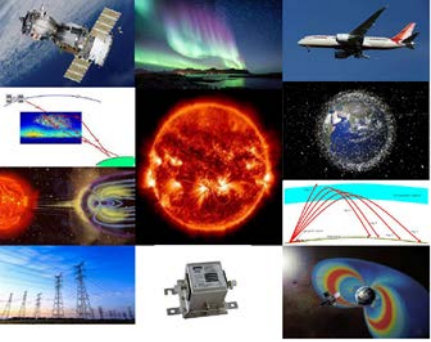
## 3. Reduce the research-to-operations gap



# CME / Geomagnetic focus

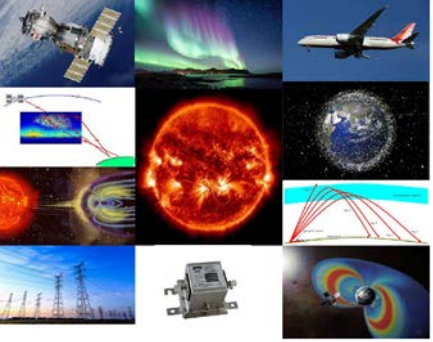






# Delivery Mechanisms

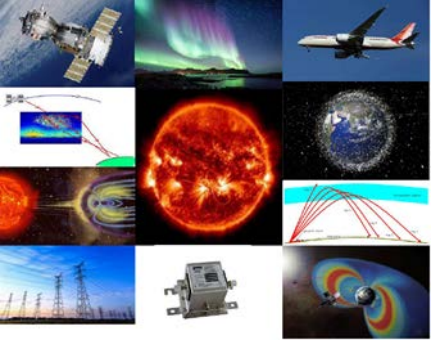
- S1, S2, S3 will be mainly delivered through contracts with STFC
  - Budgets will be held at RAL Space
  - Some internal work will be done in STFC, using own staff and facilities
  - Reports, instrument builds etc. will be procured using ITTs
  - Met Office not funded directly, will get contracts from STFC
  - May be a grant-like element in S1 to facilitate academic involvement
- S4, S5, S6 will mainly be delivered via open call grants from STFC
  - Budgets will reside at Swindon Office
  - First AOs should appear in Spring 2020
  - Grants will be less than three years (to end by 31/03/2023)



# Origins of the Programme (1)

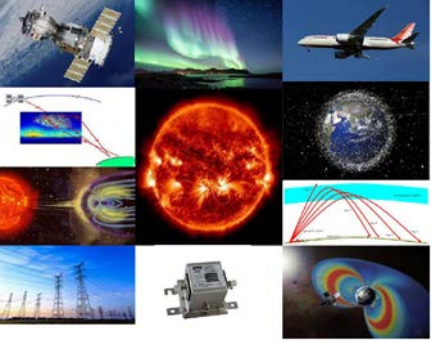


- STFC conducted a “Priority projects” exercise in July 2018
- Submitted three applications, for different combinations of space weather and space surveillance ideas
  - Space weather ideas based on previous discussions with Mark Gibbs
- STFC Director of Strategy asked for the space weather proposal to be turned into a bid to Strategic Priorities Fund Wave 2 (October 2018)
  - Suggested amount £5M



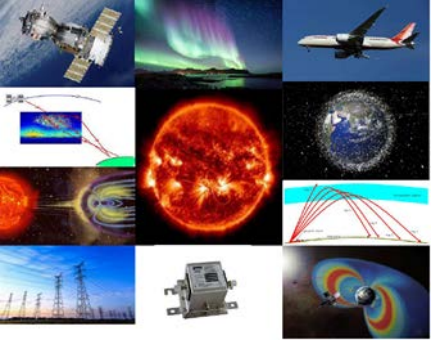
# Origins of the Programme (2)

- STFC Executive Board approved SWIMMR as an STFC-led SPF proposal (November 2018)
- Contacts with Wave 1 projects revealed the need for cross-Council and ministerial support
- Initial description, budget and ministerial support letter
  - Submitted to UKRI December 2018
  - Support letter signed by three ministerial CSAs



# Origins of the Programme (3)

- UKRI asked us to prepare full business and economic case
  - Submitted March 4<sup>th</sup> 2019
- UKRI gave outline approval of business case
  - May 2019
- Treasury approval secured on July 5<sup>th</sup>
  - Conditional on final approval by BEIS
- Signed off by BEIS Project Investment Committee on August 15<sup>th</sup>
- Announced (by the Prime Minister) on September 23<sup>rd</sup>



# The SWIMMR Planning Group



- Met as an informal group to pilot the proposal to where it is now.
- Had its last meeting last week, as programme is handed over for kick-off
- We owe them huge thanks for steering SWIMMR through the various hurdles.
  
- Mark Gibbs and Simon Machin (UKMO)
- Richard Horne (BAS)
- Keith Ryden (Univ. of Surrey)
- Paul Cannon (Univ. of Birmingham)
- Jacky Wood, Gemma Truelove and Stephen Elsby (NERC)
- Jason Green and Justin O'Byrne (STFC)
- Mike Hapgood, Mila de Vere, Toni Cullum (RAL)