

# Topical Discussion Meeting report

Name of the meeting:

**Meeting Defence Needs: Tailoring Space Weather Services for Military Operations**

Convener/s:

Michaela Brchnelova (Nederlandse Defensie Academie)  
Judith de Patoul (Royal Observatory of Belgium, SIDC/STCE)  
Steven Dewitte (Royal Observatory of Belgium, STCE/SIDC)  
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Secretary:

**Judith de Patoul**

Date – Time – Room:

Oct 28, 2025 - 13:30-14:30 - Idun

# of attendees (approximate): 100 - 200 (quite a few people came later in)

# Speakers, if any (names and institution):

**Simon Machin** (UK Met Office):

Ex-Chair of the NATO Military Space Weather Technical Panel (MILSWx), oversight of SW services and direction of scientific research to operations.

**Yana Maneva** (Royal Observatory of Belgium, SIDC/STCE):

SW service provision for PECASUS (civil aviation) and collaboration with NATO MILSWx and Belgian Defense.

**Patrick Perron** (NRCan, Canada):

Retired Signal Officer during operations in Afghanistan & Latvia teaching and training at the Royal Military College of Canada

**Petra Vanlommel** (Royal Observatory of Belgium, SIDC/STCE):

Training at the Space Weather Education Centre (SWIC), and operator for PECASUS (civil aviation).

Form of TDM:

Panel Forum

## Objective of the TDM

As military operations increasingly depend on GNSS, satellite communications, HF radio, and surveillance assets, understanding and mitigating the impact of space weather has become essential for operational readiness. Especially the arctic regions have now become interesting as a result of the opening of new shipping routes and the security question of Greenland, and these are the regions most susceptible to space weather effects. However, most space weather services today are designed with civil users in mind, and there is a growing gap between scientific outputs and

actionable military needs. This panel forum will explore the specific requirements of the defense community, from NATO partners to national armed forces, for tailored space weather support. It will highlight existing practices (e.g., UK Met Office, USAF, JMG/STCE collaboration), identify operational needs in areas such as forecasting, system vulnerability assessment, and training, and discuss how to move from physical space environment monitoring to mission-relevant, impact-oriented products. Key questions include: - What are the most critical defense use cases affected by space weather? - How can we translate forecasts into platform-specific operational risks? - What infrastructure and standards are required to support autonomous, secure defense operations under space weather influence? - What are the current gaps in space weather services as perceived by defence users? The session encourages active participation to clarify shared needs, foster civil-military cooperation, and help shape future space weather services that are operationally relevant to defense actors.

## **Discussion highlights**

This TDM examined defence use cases that are sensitive to space weather across GNSS positioning and timing, satellite communications, HF radio, radar, and ISR, with recurring emphasis on Arctic and other high latitude operations as well as eastern and southern theatres. The discussion distinguished what commanders need at decision time from scientific indices, focusing on onset, duration, geographic footprint, severity, and confidence, and highlighted the persistent uncertainty in footprint and time to recovery due to ionospheric variability.

A major thread covered translation of science into operational language. Participants contrasted product centered training that builds literacy from Sun to Earth with user centered training that starts from mission tasks, locations, and timelines. Role specific competencies for meteorology units, communications and navigation engineers, and intelligence analysts were outlined, along with the need to separate natural environmental effects from equipment faults and adversarial actions.

Policy and governance aspects were discussed in terms of classification constraints, secure data exchange, service continuity, and public funding models. The conversation linked these enablers to the reality of limited user feedback from operational communities, the importance of trust, and the need for low friction reporting mechanisms after events.

Data, validation, and modeling formed a second technical core. The panel discussed anonymised incident information, minimal incident schemas, and systematic correlation of observed effects with indicators and model fields. Open anomaly sources were noted as partial proxies. The limits of current models were acknowledged, and impact modeling was identified as a distinct step beyond environment prediction.

Timing and product alignment with defence planning cycles received focused attention. Requirements spanned immediate nowcast for short lived phenomena such as solar radio bursts, through 72 hour air tasking cycles and roughly 96 hour land planning cycles. The discussion also addressed global coverage versus monitoring constraints, particularly for scintillation, and the heightened vulnerability of platforms with limited redundancy such as low cost uncrewed systems. Product design themes included simple commander facing presentations that integrate severity, timing, footprint, uncertainty, and expected recovery into existing workflows.

## Main conclusion of the meeting

- Communication shift: scientific prose is not actionable at decision time. Use plain operational language that maps observations to decisions.
- Training origin: a failed 2017 attempt to use an SIDC bulletin led to targeted training for defence users.
- Shared needs: defence needs mirror civil ones (HF, GNSS, system degradation), but with tighter timelines and security constraints.
- Trust and language: two immediate challenges are a common operational lexicon and trusted, reliable services that users can adopt and implement.
- GNSS precision: users need high-confidence statements on location, timing, duration, and severity of effects, not just classifications.
- Rising attention: interest has grown over 10 to 20 years due to interdependent infrastructure and new theaters including the Arctic, plus pan-domain coordination with civil, commercial, and emergency actors.
- Commander's trust limiters: insufficient measurements for full validation, model limitations by region and parameter choice, and strong spatial-temporal intermittency in the ionosphere.
- High-confidence case: during S1–S2 proton events, HF communications in polar cap regions are likely impacted; uncertainty lies in exact footprint and duration.
- Validation agenda: improve impact matrices and conduct cross-comparisons that connect forecasts and indices (X-ray flux, proton flux, geomagnetic indices) to observed mission impacts.
- Two training approaches: product-centered (Sun to Earth) and user-centered (mission need to cause). Always tailor to role and level; start with simple rules users can apply immediately.
- Role-targeted training: METEO units translate advisories for commanders; comms and intelligence personnel need deeper awareness to run mission-specific impact risk assessments.
- Sensitive data: impact details are restricted; collaboration requires trust, security clearances, and proof of safeguards before sharing thresholds and system specifics.
- Mission-by-mission risk: assessments must be redone for each mission, configuration, and level (strategic, operational, tactical) with residual risk owned by the user.
- Policy and funding: sustained public investment is necessary. The UK experience shows benefits of government-backed programs and also exposes communication gaps during a recent G5 event.
- Feedback reality: cannot be mandated; users are overloaded and lack time for post-incident analysis. Engagement improves when users experience repeated impacts; approach them immediately after events.
- Differentiation: distinguish space weather effects from other natural or human-made causes. Embedded expertise inside defence organizations helps.
- Data for impact science: propose anonymized, unlabeled operational time series for blind correlations with space weather indices; teach users what to share and how to filter.

- Open proxies: civil anomaly disclosures (for example EUMETSAT) can inform impact understanding even if translation to defence is not one-to-one.
- Impact modeling: move beyond environment modeling to explicit modeling of possible operational impacts. Treat this as an international priority.
- Global coverage: nowcast and forecast products need global reach. TEC and absorption can be global; scintillation services remain limited to monitored regions, and reliable global scintillation modeling is very difficult.
- Timing alignment: align products with military planning cycles (about 72 hours for air, about 96 hours for land) and provide robust nowcasts; accept that very short-lived phenomena like solar radio bursts are not practically forecastable.
- Incident example: a suspected solar radio burst triggered a costly scramble, underscoring the need for rapid after-action analysis.
- Drones and autonomy: cheap and COTS-heavy platforms may lack redundancy and be more vulnerable; large fleets require more coordination and raise systemic risk and may need earlier warnings.
- Security and resilience: observations often come from scientific institutions with funding constraints. Defence users will demand high availability, integrity, source awareness, and strong cyber, physical, and personnel security across the chain.
- Human-in-the-loop: real-time expert assessment remains essential alongside models.
- Next engagement steps: plan regular workshops, learn and speak user language, take relevant operations courses, strengthen two-way feedback, and invite more operational defence participants to future meetings.

## Annexes

Discussion minutes:

### **Session opened with: from your perspective today, what are the defence needs and the current challenges for the space weather community?**

In 2017, a defence team in the Netherlands tried to use an SIDC space weather bulletin. They were interested but could not extract actionable guidance. They needed baseline knowledge, which led to targeted training and education for these end users. The core challenge is communication: defence personnel cannot act on pure scientific language.

Defence needs are largely the same as in the civil sector, including managing degradation of technical systems during events. The main challenges are: 1) speak a shared operational language so outputs are actionable for decision making; 2) build trust by providing reliable services that users can adopt and implement.

GNSS impacts include loss or degradation. High precision is required, as in aviation. Users want to know where and when effects will occur, for how long, how severe, and with high confidence for their infrastructure. The challenge is delivering directly useful, impact-focused services beyond classified or purely descriptive information.

Defence interest is much higher than 10 to 20 years ago. Infrastructure is more interdependent and vulnerable than during the Cold War. Conflicts are changing in type and geography, with more activity in the Arctic, and require coordination across commercial, traditional, and emergency domains in a pan-domain environment. Users want insight into impacts on their own infrastructure and awareness of potential effects on an adversary's systems.

**[Convener transition]: We have a shared understanding of needs and challenges. As a commander, how much would you trust current services? Where are the gaps and limitations? What validation is missing, and where is the uncertainty?**

Insufficient measurements and incomplete validation were highlighted. From a forecasting perspective, trust is bounded by service and model limits. Priorities include improving impact matrices and performing cross-comparisons between forecasts and observed impacts, with empirical correlations across indicators such as X-ray and proton flux and geomagnetic indices to link models to effects. Model weaknesses exist by region and parameter choice, and ionospheric variability creates strong spatial and temporal intermittency, so impacts can fluctuate even when the trend is present. Real-time human expert assessment that accounts for context and environment remains essential.

**[Convener transition]: You can provide information, but recipients also need context and background to use it, which brings us to training. This links to our second online question: Training, challenges, and what to do better?**

Two approaches are used. Product-centered: start from existing outputs, build literacy from Sun to Earth. User-centered: start from mission needs, location, timing, and technology in use, then link back to causes. Training is on request, tailored to level, and delivered in a common operational language. Forecasts should be rephrased away from academic style, starting with what is known and simple rules that enable quick assessment without deep science; for example, radar users can learn quickly when night conditions imply no impact.

**[Convener transition]: From a signal officer's perspective, how would you assess these training approaches, and what products would you need if you were still operating with space weather constraints?**

Training should raise awareness selectively. Meteorology units can translate advisories for commanders. Communications engineers and intelligence personnel need deeper awareness to perform mission-specific impact risk assessments. They need provider support but cannot do it alone and providers cannot do it without them. Impact data are sensitive; trust, clearances, and proven safeguards are prerequisites before sharing details to define operational thresholds. Risk assessment must be repeated for each mission, configuration, and operation. Some impacts are strategic, others operational or tactical; residual risk remains and decisions are made accordingly.

**[Convener transition]: Policy and coordination to bridge research and operations.**

One perspective cited strong public funding for national programs as an enabler, with relationships and trust central. A recent extreme-level event produced real but unevenly perceived impacts, underscoring communication challenges, possible updates to scales, and the need to highlight affected areas that users may not notice. Space weather is not a profitable market, so sustained public investment is required.

**[Convener transition]: User feedback and evaluation.**

Feedback cannot be mandated, so relationships and basic literacy are essential. Many users are overloaded and will ignore information they do not deem relevant. Operational personnel often lack time for post-incident analysis; however, growing awareness is prompting requests to rule out space weather versus equipment faults or adversarial action. Repeated impacts under similar conditions drive engagement, after which users may share reports and providers can analyze and learn. A practical tactic is to approach users right after notable events to elicit feedback.

Follow-on comments emphasized distinguishing natural from non-natural causes, the value of embedded expertise within user organizations, and that space weather is only one contributor among many. Translation of technical outputs into simple, immediately usable states is crucial; otherwise products will be ignored. A proposed path is to supply providers with anonymized time series from user systems for blind correlation with space weather indices, iterating without exposing system details. Users need training on what data to share. Open anomaly reports from civil satellite operators can serve as partial proxies. The next research-to-operations step is explicit impact modeling; to date the focus has been on instrumentation, measurements, and environment models, so modeling impacts should now become an international priority.

**[Audience question]: What are the main impacts across northern, eastern, and southern theaters, including satellite and ground operations?**

Training on ionospheric weather and military communications has been delivered on request as organizations rebuild HF expertise to reduce reliance on satellite communications. Cross-disciplinary centers combine ionosphere, GNSS, and solar physics competencies. Likely impacts include solar-flare-driven HF radio blackouts and issues at higher HF, along with GNSS degradation tied to ionospheric gradients; users must also think globally due to deployments beyond home regions. An example highlighted that air policing missions in high latitudes often catalyze awareness. Global coverage emerged as a requirement. Some services can provide global TEC and absorption fields, but scintillation products are limited to monitored regions. Users want global scintillation models, yet different generation mechanisms in equatorial and polar regions make reliable global forecasting extremely difficult.

**[Convener transition]: Product timing versus operational cycles.**

Operations are managed while planning ahead on fixed horizons, for example 72 hours for air missions and about 96 hours for land components. Users need awareness of forecast limits, such as CME arrival uncertainty, plus robust nowcasts for rapid response. Some phenomena, like solar radio bursts, are so short-lived that forecasting is not feasible; a recent case linked a burst to a costly scramble, motivating after-action analysis.

**[Convener transition]: Rising use of inexpensive autonomous systems.**

Drones and other uncrewed systems often rely on COTS components and may lack redundancy. Parts of industry have only recently learned of space weather relevance, so education and guidance are needed. Large fleets introduce systemic risk. Such platforms may be relatively sensitive to geomagnetic storms and could require earlier warnings, especially given the absence of onboard pilots.

**[Convener transition]: Do scientists working with military users or critical data streams become targets?**

Observations largely come from scientific institutions that already struggle with sustained funding. Military users will seek data services with high availability and integrity, awareness of all sources, and strong cybersecurity and physical security across partners and observatories. In that sense, the military would be responsible for ensuring safety of their critical information sources.

**[Convener transition]: Additional audience input.**

[Audience Comment]: Many sectors do not perceive a need because they lack awareness. First steps are convincing them through training and clear pedagogy. End users often want a simple operational answer, for example the usable frequency at a given time and location. Operators need quick answers without physics, and analysis must distinguish natural from human-made causes.

**[Convener transition]: Closing thoughts and short summary.**

Speakers converged on data resilience, provenance, and assurance, and on mapping what fails and in what order if information is lost. This was described as an early but necessary bridge between academic work, service provision, defence, and end users. Policy views suggested moving beyond an emergency-management framing toward critical-infrastructure resilience, national security, and sovereignty. Engagement and trust grow through regular workshops and by learning user language and operations, including taking relevant courses. Thanks were offered, and a live summary was promised.

**[Convener Closing the meeting]:** Over the last decade, interest from defence has increased with system vulnerability and changing conflict types and geographies. Users need to know when events are natural and when they are not. Defence needs the community's expertise, but this requires shared language and strong communication channels. Training should flow both ways, from academic to operational and from impact back to causes. Relationships and trust are essential. Users want accuracy and real-time precision, yet human expert assessment remains vital alongside models. Providers should deepen understanding of user operations, while users should contribute feedback to enable better impact modeling. The discussion should continue, with more direct participation from military users at future meetings. Final thanks were given, with an invitation to continue the exchange during breaks and in follow-up channels. **Key takeaways:** interest is rising due to vulnerability; space weather must be translated into operational terms; training needs both product-centered and user-centered paths; trust, funding, validation, and impact modeling are critical; human-in-the-loop assessment is required; build feedback loops to refine impact products; invite more operational users next time.