Space weather issues for defence and security

Mike Hapgood and Ruth Bamford

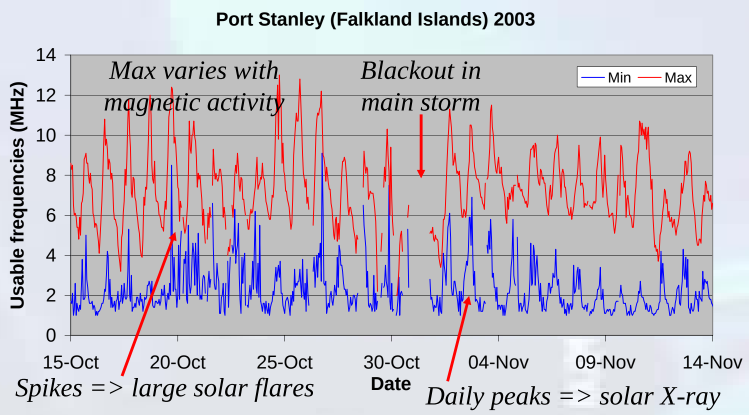
Rutherford Appleton Laboratory, Chilton, Oxfordshire, UK (M.Hapgood@rl.ac.uk)

WHAT IS SPACE WEATHER ?

- Changes in space that affect human beings and/ or technological systems
- Major impact on **environments** used by defence and security systems
- **Design, operation & regulation** of such systems must be space-weather aware
- **Knowledge transfer** to **industry** & **policy-makers**
- SpW effects are **diverse** – show a few cases here

CASE 1 – HF (3-30 MHz) COMMS

- Highly portable, frequency hopping for security
- Cost effective – ionosphere is free
- Any individual channel vulnerable to SpW
- Multiple channels reduce vulnerability [1]
- Situational awareness improves channel selection [1]
- Especially during major SpW events – see below:



Data: PPARC/UK Solar System Data Centre

CASE 2 – SATCOM

- Ionospheric scintillation degrades signals up to at least S-band
  - Can lose phase lock (also GPS)
  - Important at low and high latitudes – see right

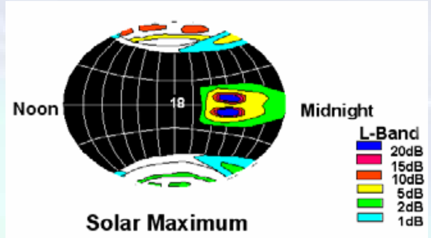
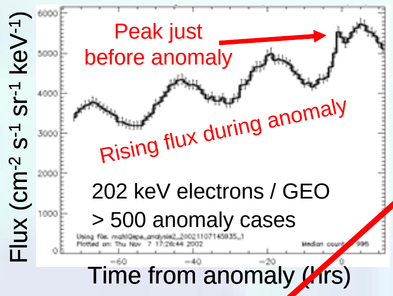


Figure: courtesy USAF



Data: MSSL

- Spacecraft at risk from charging especially in GEO
  - Discharges cause anomalies (see right) and damage
- Also subject to radiation effects
  - Single event upsets and worse
  - Degradation of electronic circuits

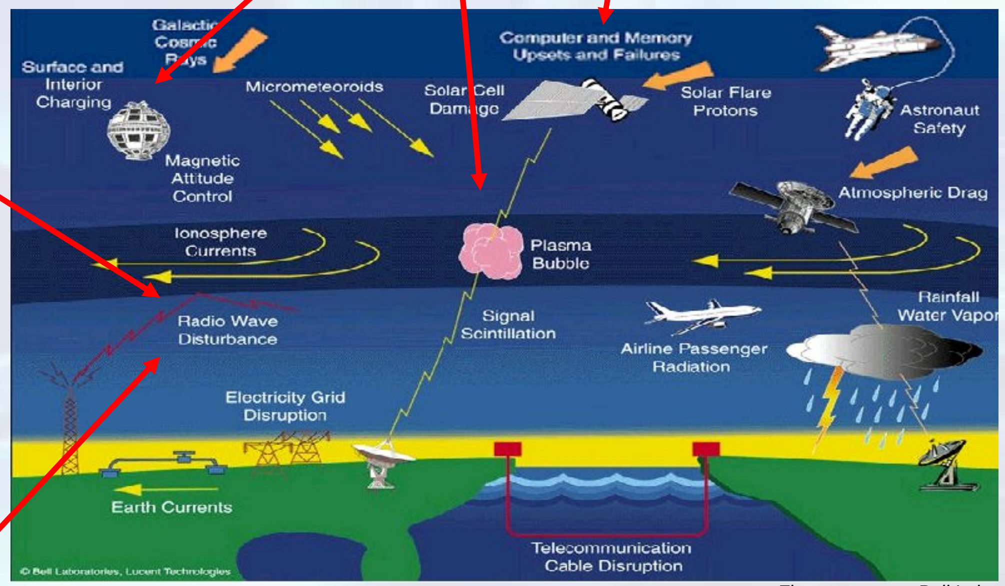
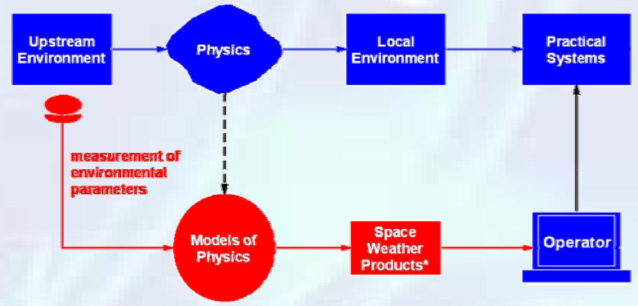


Figure: courtesy Bell Labs

WHAT CAN WE DO ABOUT IT?

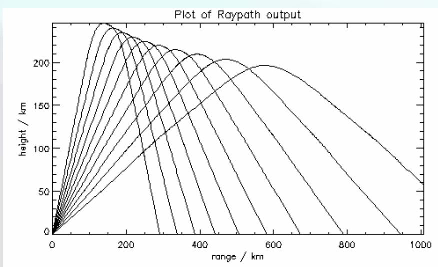
- Ideal is to mitigate space weather problems by engineering design
  - requires **specification** of relevant SpW environment and **modelling** of its interaction with system at risk
- But full mitigation is rarely feasible
  - mix engineering & situational awareness to handle problems
  - requires **nowcasting/forecasting** of SpW
- We also need **post-event analysis** of SpW problems
  - to learn from problems – improve operational procedures
  - to assess performance against formal requirements



- All approaches involve modelling of space weather environments as shown above
  - **Physics-based modelling preferred** (enables better understanding of engineering margins) – otherwise must use conservative statistical models (large margins)
  - Focus for knowledge transfer is **adaptation of models** from science to engineering use
  - Key opportunity for PPARC community – **improve physics understanding behind SpW** and feed this into **better models**
  - Vital to **raise industry & policy-maker awareness** of capabilities within the community

CASE 3 – IONOSPHERIC RADIO RAY TRACING

- Ray tracing central to many applications:
  - HF, satcom and GPS (as cases 1 & 2)
  - Advanced applications (right)
- Accuracy depends on ionospheric models
  - Good SpW modelling essential, especially during major SpW events



Advanced applications:

- over-the horizon radar
- single-station location direction finding
- jamming and interception vulnerability estimation,
- tracking of satellites/orbiting debris/ballistic projectiles
- satellite geolocation of VHF transmitters,

EUROPEAN PERSPECTIVE

- **COST actions** for scientific research
  - 296 – ionosphere & radio
  - 724 – space weather prediction
- **Space Weather Working Team** for applications
- **DIAS network** for ionospheric monitoring
- ESA encouraging technical networks where it has remit
  - Pilot SpW applications via **SWENET**

REFERENCES

1.Goodman, J.M. et al, 2006, Practical measures for combating communication system impairments caused by large magnetic storms, Radio Science 41, doi:10.1029/2005RS003404.